Concrete Silos

Lehigh Portland Cement Company

Allentown and Chicago

CONCRETE SILOS

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What Silos Are.

A silo is a tank in which fodder may be placed and preserved in a green state for feeding stock at times when a natural green pasture is not available. By the use of silos the fodder is "canned," very much as a housewife cans or preserves fruit and vegetables.

History.

Silos originated in France, but early in the 60's crops were successfully stored in Germany. During the last twenty years our State Experimental Stations, founded by the U. S. Agricultural Department, have experimented with the use of forage stored in this way, and their great success has caused the building of many thousand silos in this country.

Farmers have introduced this method of feeding with doubt as to its economy and success, but once having installed the silo, are unanimous in its praise.

Their Use.

At first this canned fodder (called silage) was only fed to milch-cows, but, thanks again to our admirable system of agricultural experimental stations, it has been found that silage may be economically fed to steers, horses, hogs, sheep, and chickens, as a partial feed. By using a silo, fodder in a green state can be fed during winter, when there is no natural pasture, and during the dry summer months, when the pastures have been eaten off. As our population has increased, the size of the average farm has decreased until it is necessary for the farmer to use all his land to the best advantage. It is, there-

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fore, not surprising that the progressive American farmer is taking advantage of the up-to-date methods of silage feeding, as published by the experimental stations, and is building silos.

Advantages of Silage.

1. The value of a crop preserved by the use of a silo is increased about 40 per cent. over that of a crop harvested in the usual way.

2. At a conservative estimate, two cows can be kept by feeding silage at the cost of one cow from the same acreage, fed on hay or other roughage.

3. The moderate cost of husbanding into silos compared to the cost of making hay, husking corn, or shredding fodder:

Actual cost of filling 100-ton silo in 1903:		
6 men loading silage in field, at	$1.50	$9.00
5 men and teams hauling silage from fields, at	3.00	15.00
3 men in silo, at	1.50	4.50
1 man at table, at	1.50	1.50
Machine, 10 hours, at	1.25	12.50
Fuel		5.00
Cutting 6⅔ acres corn, at	.75	5.00
Twine		2.12
Total		$54.62

Or, a cost of $0.546 per ton.

4. Convenience in feeding and economy of storage room. Ten tons of silage can be stored in the same space as one ton of hay.

5. When fed with the proper rations, silage is a greater milk-producer and fattener than any known feed.

6. Ensilage-fed stock, as a rule, are in a healthier state than when other feeds are used.

7. When properly taken care of, there is absolutely no waste of any part of the corn crop.

8. By providing a succulent forage, winter dairying is made profitable and no reduction of stock is caused by a dry season.

9. The acreage needed for pasture is greatly reduced and, consequently, more land can be brought under cultivation.

10. It is the cheapest feed that can be produced, as well as the best.

11. It is a certain supply, notwithstanding the drought or the flood.

12. Inclemency of weather does not hinder its harvesting.

In conclusion, we may say that a silo is the cheapest method of handling the crop, of storing it, and, finally, the best method of saving and realizing the fullest value of the crop as feed.

The Requirements of a Good Silo.

Round silos are the best. The amount of building material required to construct a silo of a given capacity is less for a cylindrical shape than for any other form. The crop is also best preserved in a round silo, as this form renders packing easy.

While concrete may be used to advantage in any form of silo, it is peculiarly adapted to the construction of a round silo.

A Silo Must be Air-tight.

As a preserve can must be air-tight to prevent the fruit from "working," for the same reason must the silo be air-tight.

The air, which is necessarily confined in packing, causes the silage to ferment, but if no additional air gets in, the silage keeps perfectly. If the air does get in, the silage molds and the cattle will not eat it.

No building material can be made as air-tight as concrete. Builders of other kinds of silos recognize this fact, and recommend a coating of cement on the inside "to keep the silo air-tight." Most silos are used for about six months, during the winter, and the remainder of the year are empty. Wooden silos are like wooden tanks or buckets. When allowed to stand empty, they shrink, the joints open, and they leak; the air-tight silo, tank, or bucket becoming a sieve. Coating on the inside with cement prevents this for about one year, when the shrinking is repeated, and this time the cement lining cracks and again the silo becomes a sieve. In order to keep it air-tight in this way, the cement coating has to be replaced every year.

A concrete silo, properly built, is air-tight. It does not shrink in the hot, dry weather.

It does not swell up in damp weather.

A Silo Should be Water-tight.

The moisture going in with the silage should be kept in. This keeps the silage from "dry firing." A concrete silo is not only air-tight, but water-tight.

A Silo Should be Perfectly Smooth on the Inside.

Silage settles after being packed, and even the slightest roughness is liable to catch the corn-stalks and prevent their settling evenly. The silage around the air-spaces formed in this way becomes moldy and must be thrown away.

Concrete silos, when built with planed boards for inside wooden

mold, are smooth, and while it is well to place a wash upon the inside, this never has to be replaced.

Silage Must be Kept at an Even Temperature.

Concrete is one of the best known non-conductors of heat and cold. On this account, the temperature of the silage at the time it is packed will be more nearly preserved in a concrete silo than in any other kind, in spite of the prevailing outside temperature.

The Right Kind of Silo.

The value of silage properly made and properly fed is no longer questioned. Especially to the dairy farmer has the silo become an almost necessary adjunct to the equipment of the farm if the latter is to be profitable. This being true, the proper construction of a silo is a question of the highest importance. A silo adapted to general use must be cheap, durable, simple in construction, and effective in preserving silage.

Why Concrete Silos are Best.

They do not Rot.

The acids formed by the slight fermentation in the silage, caused by the air left between the corn-stalks in packing, rot out wood and eat away metal silos. The alternate wetting and drying which every silo receives also rots the wood and rusts the iron. These acids have no effect on concrete.

They are Vermin-proof.

Every farmer knows the annoyance and danger to be experienced from rats. Nothing built of wood is rat-proof, and a wooden silo makes a fine nesting-place. Air is also admitted to the silage through the rat-holes: this being well known, all companies building silos recommend a concrete floor to keep out rats.

A silo built entirely of concrete is absolutely vermin-proof.

The silo shown in Fig. 1 was built on the stock farm of John W. Boardman, Jackson, Michigan, in 1902. The silo is 16 feet in diameter and 32 feet high. The walls are 8 inches thick for the first 16 feet of height, with an offset on the outside of 2 inches at this point, making the thickness of the wall above 6 inches. The reinforcement in the walls consists of barbed fence-wire placed every 18 inches. The depth

of the foundation is 3 feet 6 inches. The roof is also of concrete. The silo has been in use for six years, and has given first-class satisfaction, keeping the ensilage perfectly. It has never cost one cent for

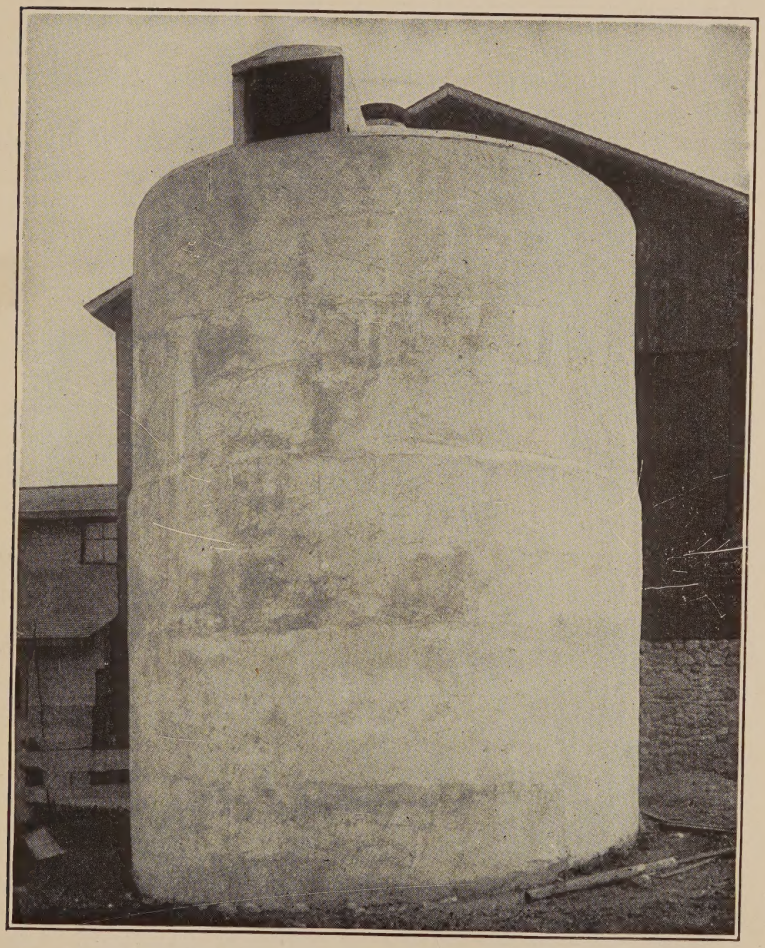


FIG. 1.—One-piece concrete silo.

repairs, and is as good to-day as the day it was built. The owner says he will build another of the same type this coming year, of increased capacity.

No Repairs Needed.

A concrete silo cannot be blown over, and if properly constructed, will last forever. It cannot spring a leak due to expansion and con-

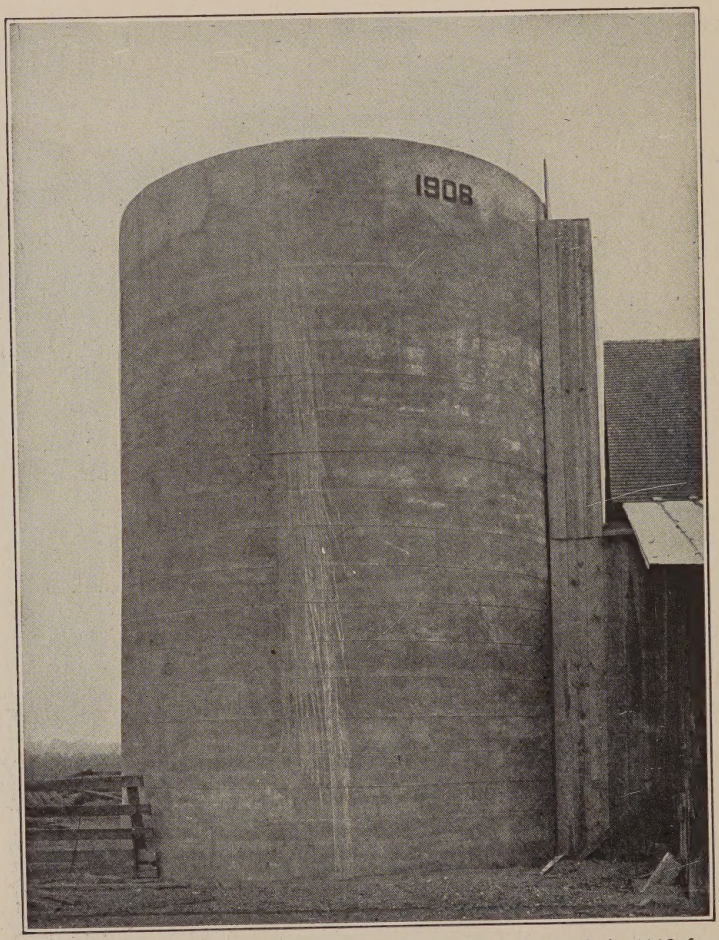


Fig. 2.—This figure shows a solid wall concrete silo, built in 1908 for Mr. G. W. Hillegoss, of Selbyville, Indiana. The silo extends 6 feet below ground, and is 19 feet in diameter and 30 feet above the ground.

traction. No complicated rods are necessary to pull the sides together in summer when they dry out, or to allow for swelling when the silo is filled in the fall.

No Fire. No Insurance.

Fire is the farmer's greatest dread. When a fire starts from lightning or any other cause, the farm buildings usually burn down. For this reason, insurance rates are very high, and farmers find it a great tax to protect themselves by carrying insurance. The buildings, however, are not the most serious loss; fires most often occur during the latter part of the summer or early fall after the crops have been harvested, and while the buildings can be replaced, practically the year's work of the farmer is gone. Very often the fire spreads so rapidly that the stock is also lost.

A concrete silo cannot burn down, as concrete is fire-proof; nor can the food stored in it be either injured or destroyed. A temporary structure can be erected to replace the burned building, but the crops cannot be replaced, except at great expense.

Insurance companies have recognized the indestructible qualities of concrete by making an insurance rate so low as to be within the means of every farmer.

The only objection that has ever been made to a concrete silo is its cost. The cost varies owing to the price of materials of which the concrete is made. In many places concrete silos are cheaper than any other kind; few farmers are without a gravel-pit suitable to furnish both gravel and sand of a quality proper for making good concrete.

Portland cement is being manufactured to-day in twenty-five States, and can be obtained at a reasonable cost. Under these conditions, a concrete silo is cheaper than any other kind.

The best is the cheapest, regardless of the original cost. A silo which *never leaks, will not blow over, is always ready to be filled without first repairing, requires no repairs, cannot burn down, and is vermin-proof, is certainly the best and cheapest.*

A concrete silo is all of these.

Kinds of Concrete Silos.

Three kinds of concrete silos have been in successful use for several years. These are known as Monolithic (or solid walls) Concrete Silos, the Hollow Wall Monolithic Concrete Silos, and Concrete Block Silos; all three are good, and in choosing between them, the cost, which is fixed by local conditions, should be the deciding feature, unless the location of farm is so far north that the extreme cold in winter makes a hollow monolithic wall or hollow block wall silo preferable, to prevent the freezing of the silage.

Fig. 3 shows the silo and cow barns of the Marquette City Dairy, of Marquette, Mich. This silo has monolithic, continuous, hollow, concrete walls, constructed in the same way as the silo built for the Illinois Farmers' Institute.

The silo shown in Fig. 4 was built by John Hemmer Sons, of Syracuse, N. Y., for Mr. N. C. Michels, on his farm, Green Point Road, north of Syracuse. The blocks are 10 inches in thickness, 16 inches long, and 8 inches in height, and are made with two air-chambers. The concrete in the body of the block is composed of fine crushed stone, sand, and Portland cement. The facing on both sides of the blocks

Fig. 3.—Hollow wall concrete silo.

is made of fine washed sand and Portland cement. A waterproofing compound was used throughout the mixture. This silo is 15 feet in diameter and 29 feet high. It is built upon the old foundation of a wooden silo, which was torn down and replaced by the present one of concrete blocks. The blocks were laid in Portland cement mortar, and are tied together with steel ties and wire binders between each block. The blocks were made in the summer, thus giving them a chance to age. The silo was filled to the top twelve hours after the completion of building, and has given the owner perfect satisfaction.

Selecting the Size.

The size of the silo depends upon the number of cattle to be fed and the number of days their feeding continues. It does not pay to

Fig. 4.—Block silo.

build a silo for less than ten head, but, as a friend very aptly put it, "Build a silo and get the ten head to keep."

The diameter, inside measurement, should never be more than

one-half the height, and in practice it is not found advisable to make it over 20 feet.

For convenience, we present the following table, showing the size silo it will take to feed any number of cattle for a given time.

TABLE A.

This table gives the number of cows in herd and tonnage of silage for both 180 and 240 days of feeding of 40 pounds of silage per cow, also acreage of corn estimated to fill the silo and the dimensions of the silo itself. The diameters given are such that at least 2 inches in depth of silage will be taken off daily.

Number of Cows in Herd.	Feed for 180 Days.				Feed for 240 Days.			
	Estimated Tonnage of Silage Consumed	Size of Silo.		Corn Acreage Required at 15 Tons to Acre.	Estimated Tonnage of Silage Consumed.	Size of Silo		Corn Acreage Required at 15 Tons to Acre.
		Diameter.	Height.			Diameter.	Height.	
	Tons.	Feet.	Feet.	Acres.	Tons.	Feet.	Feet	Acres.
10	36	10	25	2½	48	10	31	3½
12	43	10	28	3	57	10	35	4
15	54	11	29	4	72	11	36	5
20	72	12	32	5	96	12	39	6½
25	90	13	33	6	120	13	40	8
30	108	14	34	7½	144	15	37	10
35	126	15	34	8½	168	16	38	11
40	144	16	35	10	192	17	39	13
45	162	16	37	11	216	18	39	14½
50	180	17	37	12	240	19	39	16
60	216	18	39	14½	288	20	40	19
70	252	19	40	17	336	..	..	..

As stated above, the number of animals to be fed should determine the diameter of the silo, and the length of time silage is wanted should determine the height of the silo. The amount of silage to be fed per cow must be determined first. Decide whether each cow is to have 20, 30, 40, or 60 pounds per day. Then having decided this point, make the diameter of the silo such that by feeding the cows so much per day the silage can be fed down at least 2 inches per day, as this will prevent molding of silage. If a silo is made too large in diameter, —and this is the most frequent error,—one of two things will happen. *First,* the silage will be moldy all the time, owing to the inability to feed it down rapidly enough, or, *second,* the cows will be fed more than they should have in an attempt to keep ahead of the molding.

Where large cows are kept and it is expected to feed 40 or 60 pounds per cow daily, it frequently happens that it is desirable to cut down

the silage ration. It is well to have the diameter of the silo small enough so that the ration can be cut down one-third or even one-half and still be able to feed down the silage 1 to 1½ inches daily.

Fig. 5 shows the two concrete silos of John D. Baltz, Kennett Square, Penna. As about seventy-five head of cattle were to be fed,

Fig. 5.—Double solid wall concrete silos.

two medium-sized silos were built in preference to one large one. They are 15 feet 6 inches and 17 feet inside diameter respectively. They are 40 feet high, and extend 20 feet below the ground-level. The walls vary in thickness from 10 inches at base to 7 inches at top.

In the older dairy sections, where silos have been longest in use and dairymen have used up their first wood silo and are building

the second time, they build two small ones in place of the one large one. They also build smaller in diameter and higher.

In the dairy sections many farmers consider this point so important that they are building two small silos instead of one large one, so that they can feed a light ration and still feed down the silage rapidly enough to prevent molding.

About fifty cows seem to be the most that can be fed with advantage from one silo. In general, 40 pounds of silage is figured as the average daily feed of a cow.

For further convenience in figuring in connection with the size and capacity of silos, we present Table B.

TABLE B.—THE APPROXIMATE CAPACITY IN TONS OF ROUND SILOS.

(The diameter is shown at the top of the columns and depth at the left.)

Height of Silo.	Inside Diameter of Silo in Feet and the Capacity in Tons (2,000 lbs.).										
	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.	16 ft.	17 ft.	18 ft.	19 ft.	20 ft.
Feet.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
20	26										
21	28										
22	30	36									
23	32	39									
24	34	41	49								
25	36	43	52								
26	38	46	55	64							
27	40	49	58	68							
28	42	51	61	71	83						
29	44	54	64	75	87						
30	47	56	67	79	91	105					
31	49	59	70	83	96	110					
32	51	62	74	86	100	115	131				
33	53	65	77	90	105	121	138				
34	56	68	80	94	109	126	143	162			
35	58	70	84	98	114	132	149	169			
36	61	73	87	102	118	136	155	176	196		
37	63	76	90	106	123	142	161	183	204		
38	66	79	94	110	128	148	167	191	212	237	
39	68	82	97	115	133	154	174	198	221	247	
40	70	85	101	119	138	160	180	205	229	256	280

Construction of Various Forms of Concrete Silos.

First decide the kind of a concrete silo best adapted to the locality where it is to be built. Cost usually decides the class of concrete silo, except where extreme cold weather makes a hollow wall necessary.

All concrete silos preserve silage equally well. The effect of freezing silage should be considered in the Northwest, and the form of construction best adapted to prevent it is known as a hollow wall silo.

Solid Wall Concrete Silos.

The solid wall concrete silo is cheap, easily built, and fulfils all the requirements of a perfect silo. This type has been extensively used.

These were first built with very thick walls, and without steel reinforcement. By using steel reinforcement,* a greater strength can be obtained with a much thinner wall. This saves in the quantity of concrete used, and also in the cost of material and labor.

For solid wall concrete silos we therefore recommend thin reinforced walls rather than thick walls, without reinforcement.

Hollow Wall Monolithic Concrete Silo.

The hollow wall monolithic concrete silo is constructed much the same as the solid wall, except that two walls are built instead of one, with a hollow air-space of about 4 inches between them. The inner wall is reinforced in the same way as in a single solid wall silo. The only reason for the outer wall is to form the air-space between the walls. This keeps the silage from freezing.

While it takes a long period of low temperature to cause any serious freezing of silage, it is of decided advantage in handling the silage, in localities subjected to such severe cold weather, to be able to feed it to the stock without the added labor of thawing it out. Our state experimental stations are still debating the effect of feeding frozen silage, but all agree that if it is thawed out before feeding, there is no harm in it.

The labor and time lost in thawing out the silage is saved by the use of a hollow wall silo. This is quite an item in districts where the silage would remain frozen for two months or longer.

The cost of the hollow wall silo is about one-fourth greater than the solid wall silo. Except to prevent freezing, it has no advantage over the single, solid wall silo. With both types of silos, any kind of doors, roof, chute, etc., desired may be constructed with equal ease.

Cement Block Silo.

The cement block or concrete block silo is built of circular, hollow blocks, laid in cement mortar, and reinforced with steel hoops, which

* ¼ to ½ inch bars, expanded metal, wire mesh embedded in the concrete.

fit in between every second or third course according to the size and depth of silo and size of hoop. When finished, the silo is usually painted both inside and outside with a cement mortar to insure air-tightness. The block silo, like the hollow wall silo, has a dead air-space in the walls which tends to prevent freezing, although the block wall is not quite as effective in this respect as the hollow wall, since the air-space is not continuous. The principal advantage of the concrete block silo lies in the ease with which it can be constructed. It requires less labor than either of the other types, after the blocks have been made. However, since the blocks are usually bought of some block manufacturing company, their cost often makes this type of silo the most expensive, and this fact must be given due consideration.

If the farmer lives in a district where cement block, hollow wall, or solid wall silos are constructed, he should get prices from the various concerns in the business, and compare these with an estimate of what it would cost him to do this work himself, before deciding what kind of a silo to build.

If the price submitted by a concern doing this kind of work is lower than the amount the farmer estimates he can build the silo for himself, he should, of course, have them do the work. Strict compliance with the specifications as outlined in this book should be insisted upon.

Location of Silo.

In selecting a proper location for a silo the following conditions must be met: (1) The silo must be convenient for feeding. (2) Must be located on solid ground. (3) No odors from the silage should enter the barn.

1. Convenient for Feeding.

The silo should be as near as possible to the feeding stalls, preferably at the end of the feedway. Silage is a heavy feed, and some must be handled each day, and by locating the silo in this way, much labor is saved.

2. Must be Built on Solid Ground.

The weight of the silo and its contents is very great. The foundations must, therefore, be placed on solid ground, so there will be no settlement.

3. No Odors in the Barn.

Milk readily absorbs odors, and if the odor from the silage is allowed in the barn during milking-time, it can be noticed in the

taste of the milk. This taste disappears when the milk is made into butter or cheese, and in no way affects the keeping qualities of the milk.

Ordering Materials and Preparing to Build.

By referring to our Bulletin No. 20* the necessary tools and lumber for the concrete mixing can be ascertained.

The materials necessary for building the silo itself are as follows:

Lumber, for concrete molds (or forms), scaffolding, doors, roof, and chute.

Nails and bolts.

Gravel or broken stone.

Sand.

Portland cement.

Steel reinforcement, consisting of either iron rods, wire, or wire mesh, as the farmer may choose.

Concrete blocks (if a block silo is to be built).

From the tables which follow, the quantities of these materials necessary for building various sized silos are given.

On page 52 is a blank summary of the materials necessary to build a silo. Get the quantities needed from the tables, and when the blank is filled in, you have before you a list of all the materials necessary to be ordered.

Do not leave the ordering of your materials until the last moment. Order well in advance, so that just what is wanted will be had instead of some "makeshift," thought of at the last minute. There is no economy in buying in small lots. Since exactly what is needed is known, order it all at once, and with the material on hand, be able to rush the work to completion whenever the opportunity offers.

How to Build a Solid Wall Reinforced Concrete Silo.

We will tell you how to build a silo, 10 feet inside diameter and 25 feet high—this being a silo of average size.

Certain parts of all three kinds of silos are the same, and the building of these parts will be described once, under solid wall concrete silos.

* Bulletin No. 20, "How to Mix and Place Concrete by Hand," can be obtained free on request to your cement dealer, or by mail from the Association of American Portland Cement Manufacturers, Land Title Building, Philadelphia.

Making Excavation and Placing Foundations.

Since the silo and its contents are very heavy, it must be built on solid ground, and the bottom of the foundation must go below the frost-line.

We have assumed that a depth of 5 feet below the ground-level will be sufficient in all parts of the country. This depth will prevent any possibility of the silo being blown down, and usually furnishes good hard ground for the foundations to rest on.

Fig. 6 is a section of the excavation; that is, a drawing of how the hole in the ground would look if it could be cut exactly in half and could be seen from one side. This hole is dug larger at the top than at the bottom, to prevent the sides from caving in while the concrete is being placed. In the drawing, the distance from point O to A is the length of the string by means of which the size of the top of the hole is marked. This distance is made longer by 2 feet than the radius or length of string that is used to measure the outside circle of the foundation footings. These different lengths give a slope to the side of the excavation sufficient in all materials, except very fine sandy soil, to prevent the dirt falling into the hole after the excavation is completed.

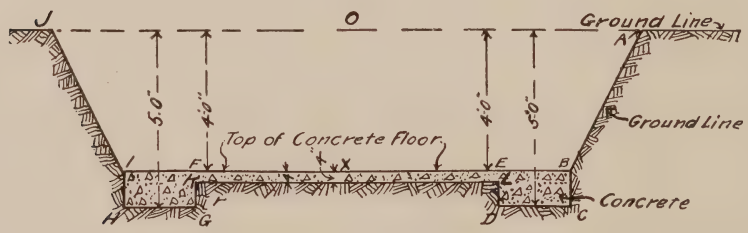


Fig. 6.—Section of excavation for foundation showing also floor and footing of silo.

Excavation.—Having selected the site for the silo, the size of the hole for the foundation must be marked on the ground.

Referring to drawing, Fig. 6:

1. Drive a stake in the ground at O, as near the center of the site selected as possible. Place a nail in the top, and with a string tied to the nail mark off a circle.

2. For the length of string, look in Table C for the distance O–A, opposite the diameter of the silo you wish to build. In the case of a 10-foot silo, this distance is 8′ 3″.

3. Dig a hole four feet deep, sloping the sides toward the center.

4. Drive a stake in the bottom of this hole, at the point marked X. This should be as near the center of the hole as possible. With a string attached to a nail in the top of this stake, mark off a circle. The length of string to be used is equal to X–B, and is found in Table C to be 6′ 3″ for a 10-foot silo. This circle will mark the outside limit of the concrete foundation of the silo.

5. Using the same stake, mark off another circle smaller than the one marked under 4. The length of the string to be used for this circle will be found in Table C under column X–E. For a 10-foot silo this length will be 4′ 3″. This is the inside diameter of the footing.

6. Dig out the earth between these two circles to a depth equal to the distance B–C, or 1 foot for firm ground and 1 foot 6 inches for medium ground.

7. Dig out the earth in the inside of the trench, as described in 6, to a depth of 4 inches.

8. Fill in the trench to a depth of 1 foot and the center of the excavation to a depth of 4 inches with a 1 : 3 : 6 mixture of concrete of medium wetness. This will make the top of the concrete in the trench and in the center the same level. The concrete should be thoroughly tamped, and the center smoothed off.

This completes the excavating for and placing of the footings.

Table C shows the width and depth of the foundation necessary for firm and medium ground.

TABLE C.

Diameter of Silo in Feet.	Length of Lines.									
	For Hard or Firm Ground.					For Medium Ground.				
	O–A	X–B	X–E	E–B	B–C	O–A	X–B	X–E	E–B	B–C
10....	8′3″	6′3″	4′3″	2′0″	1′0″	8′9″	6′9″	3′9″	3′0″	1′6″
11....	8′9″	6′9″	4′9″	2′0″	1′0″	9′3″	7′3″	4′3″	3′0″	1′6″
12....	9′3″	7′3″	5′3″	2′0″	1′0″	9′9″	7′9″	4′9″	3′0″	1′6″
13....	9′9″	7′9″	5′9″	2′0″	1′0″	10′3″	8′3″	5′3″	3′0″	1′6″
14....	10′3″	8′3″	6′3″	2′0″	1′0″	10′9″	8′9″	5′9″	3′0″	1′6″
15....	10′9″	8′9″	6′9″	2′0″	1′0″	11′3″	9′3″	6′3″	3′0″	1′6″
16....	11′3″	9′3″	7′3″	2′0″	1′0″	11′9″	9′9″	6′9″	3′0″	1′6″
17....	11′9″	9′9″	7′9″	2′0″	1′0″	12′3″	10′3″	7′3″	3′0″	1′6″
18....	12′3″	10′3″	8′3″	2′0″	1′0″	12′9″	10′9″	7′9″	3′0″	1′6″
19....	12′9″	10′9″	8′9″	2′0″	1′0″	13′3″	11′3″	8′3″	3′0″	1′6″
20....	13′3″	11′3″	9′3″	2′0″	1′0″	13′9″	11′9″	8′9″	3′0″	1′6″

Note: In a stiff firm clay O–A can be made 1 foot shorter than shown.

Cautions.—Be sure the earth under the footing is very dry and is as firm as possible. Do not remove the last 2 or 3 inches in the trench until just before the concrete is mixed. If rain interferes, always remove the softened soil and pump or bail out all water before placing the concrete.

If ground-water runs into the trench, tamp 2 or 3 inches of gravel pebbles (free from sand) in the soil before placing the concrete.

This excavation and concreting can be done in such a short time that, except in extreme cases, no trouble should come from rain. If, however, this should happen, slope the concrete floor slightly toward the middle and make a hole in the middle of the floor into which the water will drain, and from which it can be easily pumped or bailed out.

The foundation and floor are now complete and have been made without the use of forms.

If the ground is so soft that the trench cannot be dug with straight sides, a few stakes and boards can be placed around the edges of the trench to hold up the sides while the concrete is being placed. Be sure the trench is as wide as the width given in Table C.

If good ground cannot be found upon which to build the silo, the foundations should be strengthened by using the same kind of steel or wire used in the walls. This reinforcement should be placed after the first 3 or 4 inches of concrete has been deposited and while the concrete is fresh. After spreading this thin layer to a fairly smooth surface, lay the steel reinforcement on it. The reinforcement should be formed into rings or circles of varying sizes. The largest ring should be placed first and should come within about 3 inches of the outside edge of the concrete. Then another ring should be placed 6 inches inside of this first one, and then another 6 inches inside of the second, and so on until the entire surface of the footing has been covered. Short pieces of barbed wire cut just long enough to fit across the footing should then be placed over the rings. Spread the pieces of barbed wire out in a fan-like manner so that they are about 12 inches apart at the outside edge of footing. A footing reinforced in this way will settle evenly in soft ground without cracking the walls of the silo.

Silo Walls—Forms and Construction.

With the foundation and floor in place, the circular walls of the silo can be started at once. There are five operations in the constructing of the walls:

1. The forms must be built and set, ready for the concrete.

2. The reinforcement placed.

3. The concrete mixed, and placed in the forms around the reinforcement.

4. The forms removed, hoisted, and reset, ready for the next section of concrete.

5. Openings formed in walls for doors, placing of anchor-bolts for roof and chute, and other details.

We will explain the several operations in the order given, except item No. 2, which will be taken up separately under "Reinforcement," and item No. 5, which will be explained under the various headings.

1. *Wall Forms.*—The wall forms are circular in shape, one inside the other, the concrete being placed between them and thus forming the required wall. These forms are kept 6 inches apart so that the silo walls will be 6 inches thick when completed. The forms are 3 feet high, so that 3 feet of the silo can be built at one time, without shifting forms. After the first 3 feet of concrete is in place, the forms are loosened by means of the adjusting bolts shown in Fig. 8 (also details in Fig. 13), raised by the levers and again set in place by the adjusting bolts. This operation is repeated until the silo walls are built.

Both the inside and outside forms consist of pieces of 2″ x 6″ planks, cut circular.

Fig. 7 illustrates an easy method of marking the 2″ x 6″ pieces so as to saw them correctly. Take any level place in the house or barn and drive a wire nail in the floor. With a string attached to the nail, mark off a small length of a circle with a piece of chalk attached to the other end of the string, making the length of string 5 feet for a 10-foot silo. This mark gives the curve of the inside face of the form. From Table D we find the length of the 2″ x 6″ piece for an inside form for a 10-foot silo is 3′ 2″, and 20 of these 2″ x 6″ x 3′ 2″ pieces are needed. Lay one piece of 2″ x 6″ x 3′ 2″ on the curve described above and as shown in the upper half of Fig. 7.

Adjust the piece until the chalk line just comes to the outside edge and cuts both ends at an equal distance from the outside edge. Holding the 2″ x 6″ firmly, mark off the arc of the circle on it. By holding the string tight mark the cut for the two ends at the points where the curve leaves the 2″ x 6″. Use a good strong string, or, better, a light wire, so that it will not stretch. When this piece of 2″ x 6″ is cut along the marked lines, it will be a templet for the rest. After cutting five or six pieces lay them out on the circle and see how they fit the curve, making any slight corrections necessary.

The templet piece for the outside form is made in exactly the same

way, except that the length of the string is increased the width of the silo walls, a slightly longer piece of 2″ x 6″ is necessary, as shown in Table D, and the circular cut is taken out of the inside instead of the outside of the board. (See lower half of Fig. 7.)

These planks are held together by 1″ x 4″ cleats. There are four

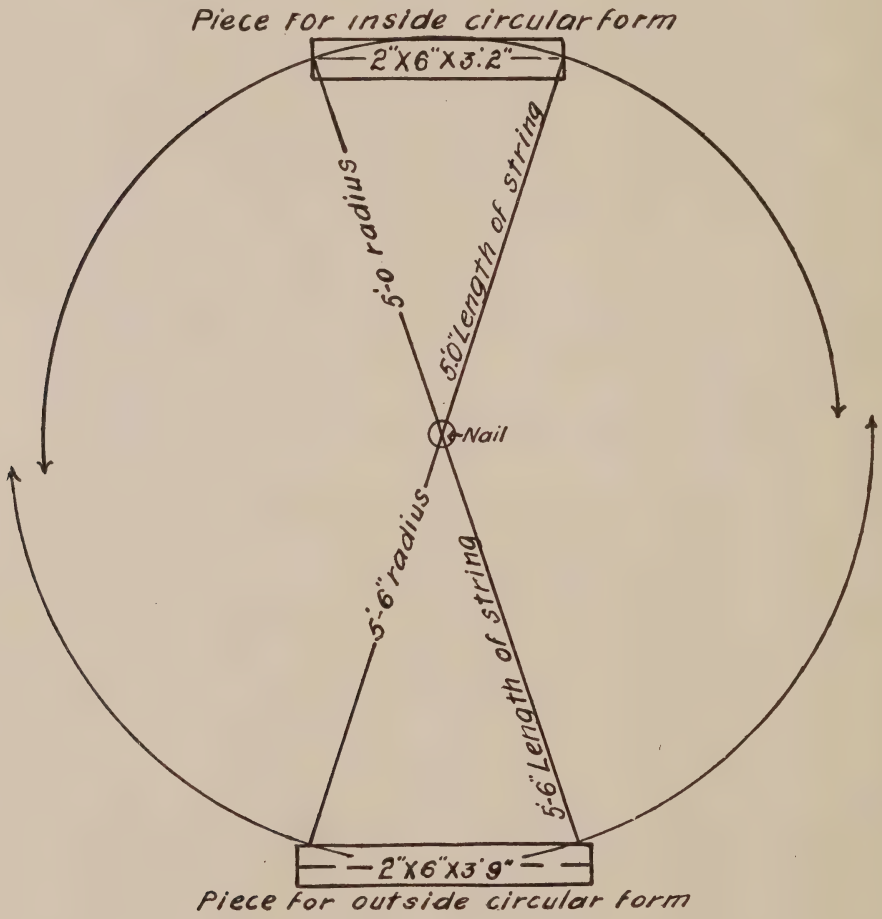


Fig. 7.—Method of making pieces to be cut for circular forms.

complete circles of these 2″ x 6″ pieces, one at the top and one at the bottom of each form. The circles are held apart by 1″ x 4″ studding placed with their edges flush with the circular side of the 2″ x 6″ pieces, two studs to each piece of 2″ x 6″ plank. This framework is further

TABLE D.

Diameter of Silo in Feet.	Inside Form.			Outside Form.			Number of Circular Pieces between Opening and Hinge.	Number of Circular Pieces to Make Section A.
	Radius of Circle.	Length of 2 x 6 Pieces.	Number Pieces Necessary.	Radius of Circle.	Length of 2 x 6 Pieces.	Number Pieces Necessary.		
10	5′0″	3′2″	20	5′6″	3′9″	20	3	14
11	5′6″	3′6″	20	6′0″	4′3″	20	3	14
12	6′0″	3′2″	24	6′6″	3′10″	24	4	16
13	6′6″	3′6″	24	7′0″	4′1″	24	4	16
14	7′0″	3′9″	24	7′6″	4′4″	24	4	16
15	7′6″	3′5″	28	8′0″	4′0″	28	4	20
16	8′0″	3′8″	28	8′6″	4′3″	28	4	20
17	8′6″	3′11″	28	9′0″	4′6″	28	4	20
18	9′0″	4′1″	28	9′6″	4′8″	28	4	20
19	9′6″	4′4″	28	10′0″	4′11″	28	4	20
20	10′0″	4′7″	28	10′6″	5′2″	28	4	20

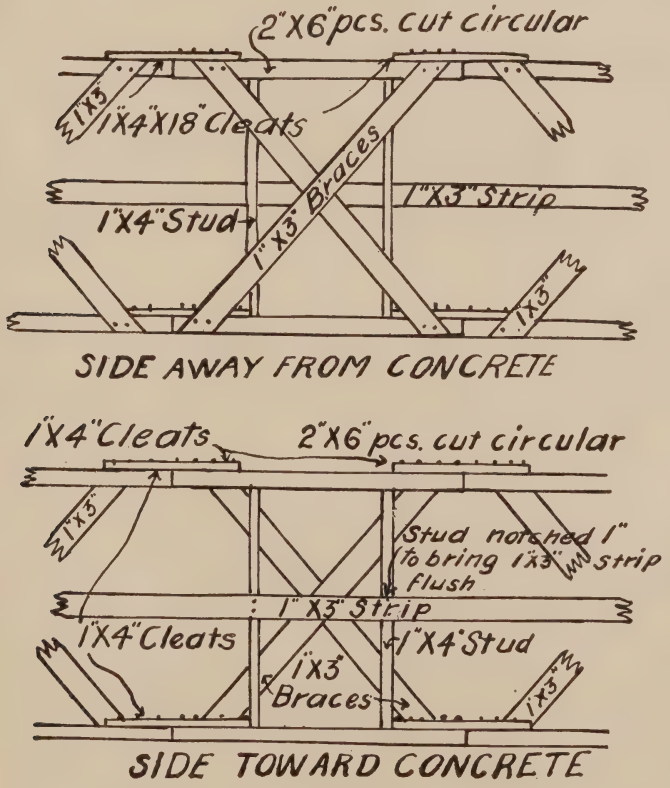


Fig. 8.—Section of framework of circular forms.

braced by 1″ x 3″ diagonal braces—a pair of diagonal braces being used for each section of the circle. A 1″ x 3″ strip is sprung around the middle of the frame, the 1″ x 4″ studs being sawed out 1 inch to receive it on the edge toward the concrete. This makes the circular

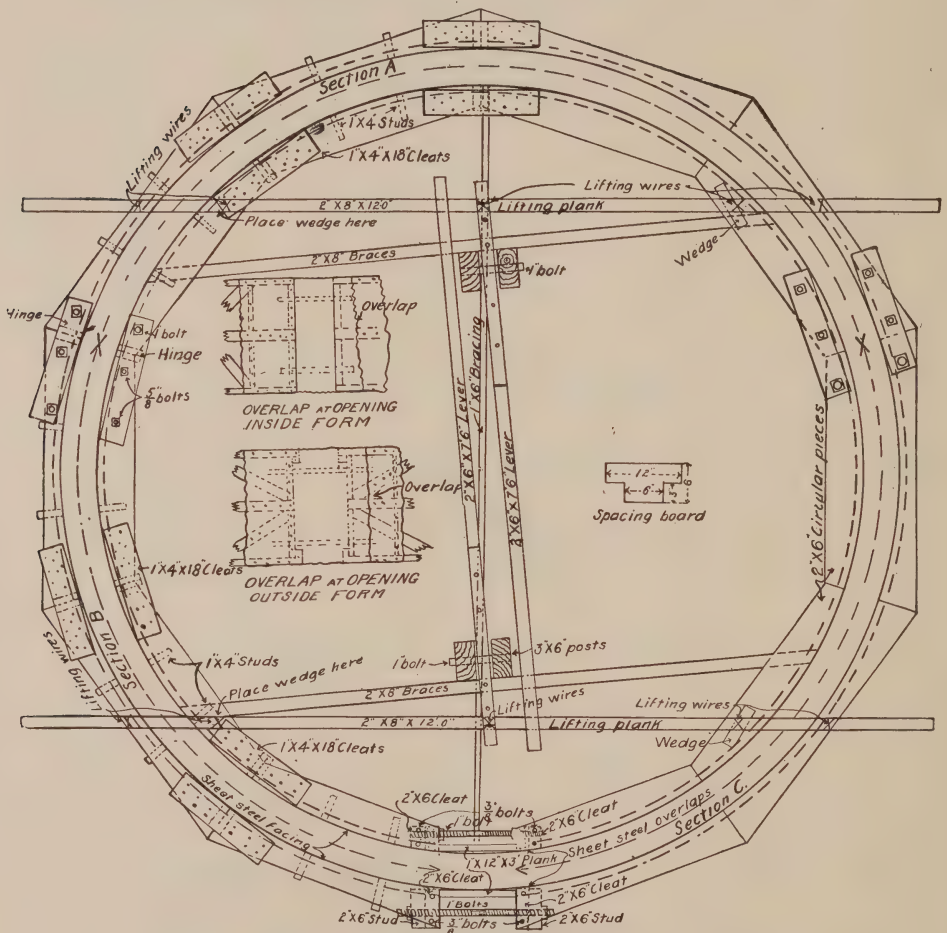


Fig. 9.—Showing arrangement of circular forms and scaffolding.

2″ x 6″ pieces, the 1″ x 4″ studs, and the 1″ x 3″ strip all flush on the face of the form toward the concrete. On this circular surface is nailed the sheet steel (No. 24 gauge) which is the real form that holds the concrete. (See Fig. 8 for details.)

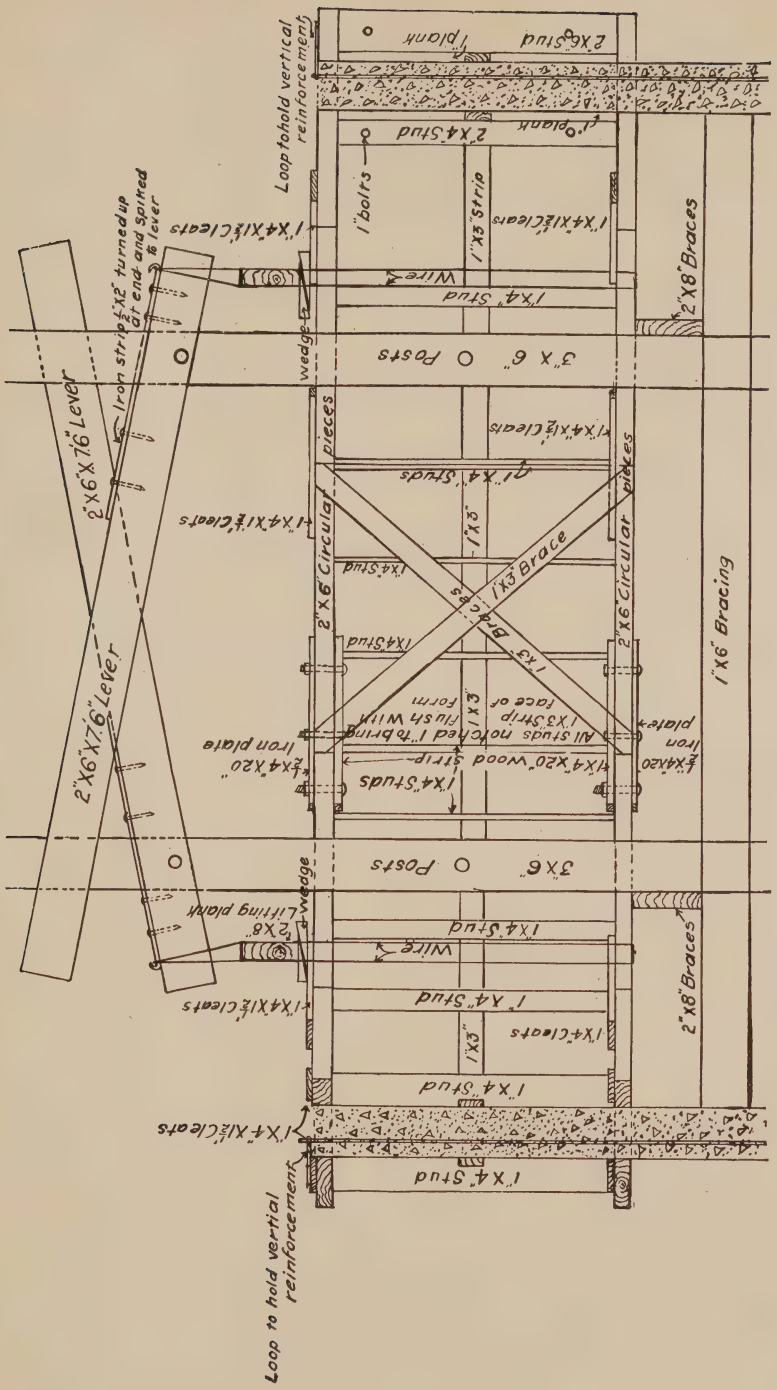


FIG. 10.—Showing circular forms, scaffolding and lifting levers.

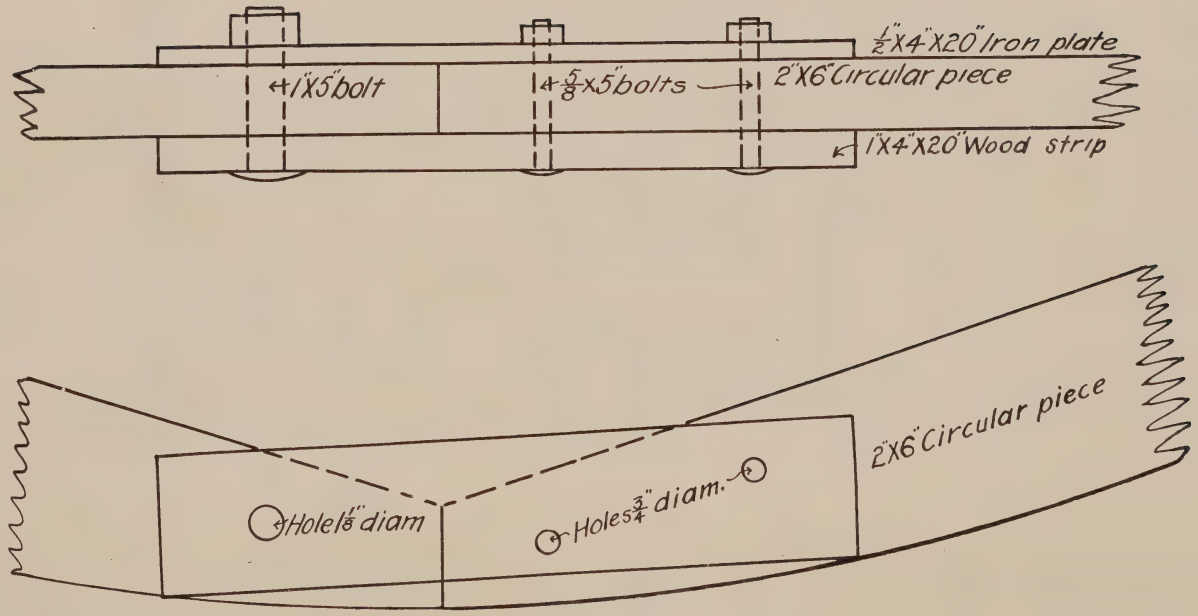


FIG. 11.—Detail of hinges.

Both inside and outside forms have screw-bolt devices for separating and pulling together the forms. Each has two sets of hinges to allow the forms to be separated or pulled together. These hinges, with the space for operating the adjusting bolts, divide the forms into three sections, lettered A, B, and C in Fig. 9.

Fig. 9 is a view of the silo forms and scaffolding as it would look to a person above the silo looking down.

Fig. 10 is a section of the silo under construction taken straight across the silo. It shows how the forms and scaffolding would look if the silo could be cut in two down the middle.

These two figures show exactly how the forms are constructed and operated. Refer first to Fig. 9. As soon as the 20 circular pieces for both the inner and outer forms are made, as described under Fig. 7, fit Section A around the circle on the level floor and nail on the cleats.

By referring to the last column in Table D, you can find the number of 2″ x 6″ pieces necessary to make this section.

Next, fit together the number of pieces necessary to make the two sections between the opening and the hinges, and marked B and C in Fig. 9. The next to the last column in Table D gives the number of pieces for each of these sections.

With the end of sections B and C about 1 inch from the ends of section A, to allow for the play of the hinges, it will be found that the 2″ x 6″ pieces will overlap at the opening. Where this overlap comes, the ends of sections B and C should each be cut back to make an opening of 12 inches. The adjusting bolts are placed in this opening.

While the 2″ x 6″ circles are lying on the smooth floor, the holes for the hinges should be bored. These hinges consist of two ½-inch iron plates, placed on both sides of the 2″ x 6″ pieces. They are fastened to the ends of sections B and C with two 1-inch bolts, and to the ends of section A with one 1-inch bolt. This bolt is not placed until the forms are in position, and is not drawn tight. This allows for the hinge action. (See Fig. 10.)

Next finish the three sections (A, B, and C) separately, placing first the 1″ x 4″ studs, then the 1″ x 3″ cross-braces, and last the 1″ x 3″ strip. This strip can stop at the last stud next to the hinges.

Fig. 11 illustrates one section of the framework of the forms, showing how the 1″ x 4″ studs, the 1″ x 3″ cross-braces, and the 1″ x 3″ strip are placed for each pair of 2″ x 6″ circular cut pieces which form the top and bottom of the framework.

Fig. 12 shows the silo of Briar Cliff Farms, New York, in the course

of construction. It is also being filled while it is being built. It is 22 feet in diameter, and 46 feet high, with 6-inch reinforced solid walls. Exterior scaffolding was used. This, however, is considerably more expensive than the method described here.

Sheet Steel.—Nail on the No. 24 gauge sheet steel. Sheets come in different sizes, and we suggest that whatever can be obtained from stock at the dealers be used. Always have a stud at the vertical seam of the sheet steel, and if a horizontal seam is necessary, move the 1″ x 3″ strip up or down opposite the seam. Also at both the hinges, let one side overlap the other about 2 inches. Take care, however, that

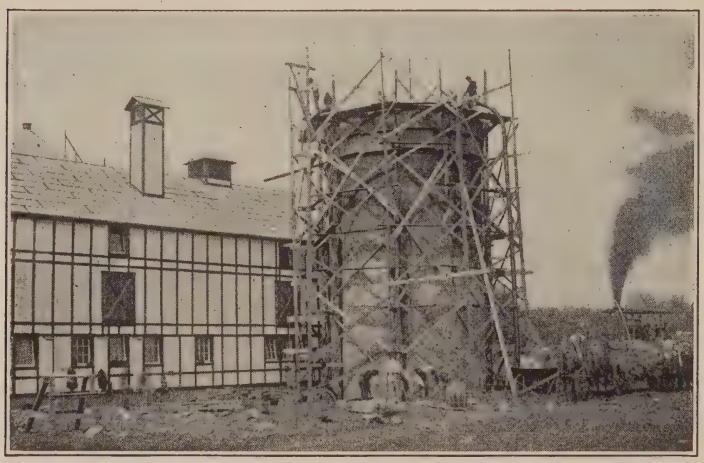


Fig. 12.—Briar Cliff Farms Silo.

this extra lapping piece does not interfere with the free operation of the hinges. If the hinges are arranged as shown in Fig. 9, the overlapping piece at each hinge should be attached to section A. There should also be 14 inches of overlap at the opening, in both the inside and outside forms, so that the full width of the top piece is next to the concrete. If there is any overlapping along horizontal seams, the top piece of sheet metal should always overlap the bottom piece.

The face of the sheet metal form should be painted with a thin coat of black or cylinder oil, and repainted whenever necessary to keep the concrete from sticking to it.

Wooden Forms.—The face of the silo wall forms may be made of

1-inch tongued and grooved boards in place of the sheet metal shown in Figs. 9 and 10. In this case, in laying out the sawing of the circular 2″ x 6″ piece shown in Fig. 7, make the length of string used for marking the inner circle 1 inch less, and the length of string used for marking the outer circle 1 inch more than shown. This is to allow for the 1-inch tongued and grooved face. Surfaced boards should be used and painted well with oil before the concrete is placed. Green lumber is preferable to dry lumber, as the latter absorbs moisture from the wet concrete and warps out of shape.

The forms are now ready to be carried to the silo site and placed in the correct position on the footing for the first course of concrete. Set up the inside form first, and level it very carefully, putting in the hinge-bolts in the ends of section A, and the adjustment bolts between sections B and C. With the use of the spacing boards shown in Fig. 9, place the outside form and then draw the upper and lower circle tight by means of the adjusting bolts. The spacing boards should be placed around the circle about every 3 feet for the first trial.

Adjusting Bolts.—Fig. 13 shows the method of placing the adjusting bolts at the opening for both the inside and outside forms. For the inside form, the nuts on the adjusting bolts are on the inside of the opening between the 2″ x 4″ pieces which make the ends of the form. To contract the inside form, turn the nuts back to the center. To expand the inside form, turn the nuts toward the ends of the bolts. The nuts on the bolts for the outside form are in back of the 2″ x 6″ pieces, which make the ends of the form and can pull the form together and hold it in place.

Place a piece of 1″ x 12″ x 3′ 0″ (2 pieces of 1″ x 6″ x 3′ 0″ nailed together) back of the sheet metal across the openings, toe-nailing this piece to the sides or holding it in place with wedges between it and the adjusting bolts. This piece must be taken out and reset each time the forms are moved.

In placing the forms, remember to place the openings in the forms directly toward the side or point at which the hoisting of concrete is to be done, when the silo wall gets above the ground. The openings have nothing whatever to do with the hoisting of the concrete, but right back of these openings will be two 3″ x 6″ posts, by means of which the hoisting is to be done.

Thickness of Walls.—The thickness of the silo wall can easily be increased over the 6 inches shown, by setting the outside form further away from the inside form and increasing its length slightly.

Placing Concrete for First Two Courses.—Everything is now ready

for the placing of the concrete, with the exception of placing the reinforcement. (Explained later.) As the second 3-foot course of concrete only brings the top of the form two feet above the ground-line, both these courses, and also the third, should be placed by shovel-

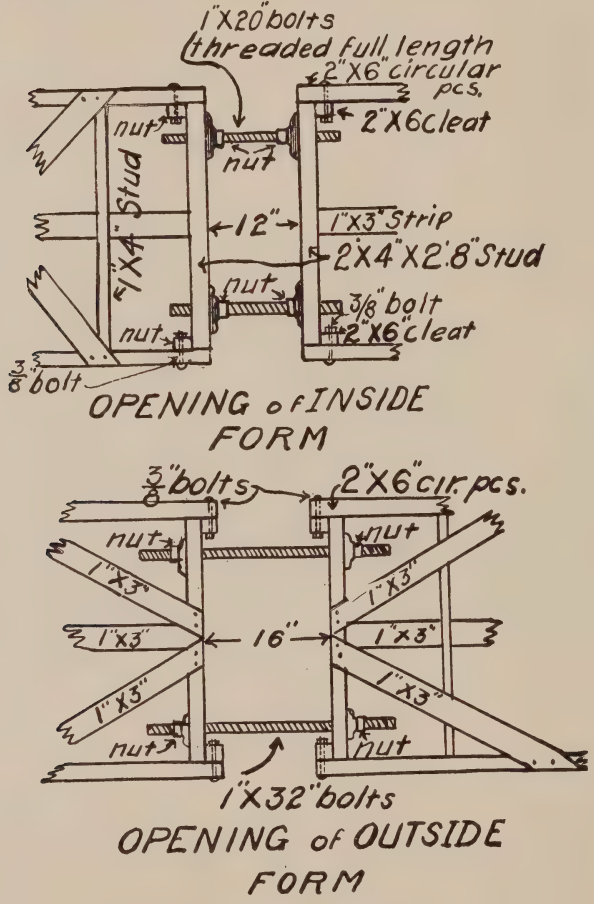


Fig. 13.—Arrangement of adjusting bolts.

ing directly into the forms from the concrete board, or by dumping the wheelbarrow loads directly into the forms, if the mixing is being done at a distance from the site of the silo. Mix the concrete wet, so that it will need little tamping. Place it in from 4- to 6-inch layers

and spade it thoroughly next to the forms. Read Bulletin No. 20* for details of how to spade, and make a wooden spading tool as described there. An iron spade is too clumsy for a 6-inch wall and is apt to catch on the nails holding the sheet metal.

Make each 6-inch layer of concrete level before starting a new layer. Before placing any concrete, the concrete already in place should be carefully cleaned off by sweeping and then flushing with water. Then scatter a few handfuls of dry Portland cement over the old concrete. This should be done each time before starting to fill the forms after raising.

Fill the form flush with the top and carefully even off the edges. Rough up the center of the top of the concrete as much as possible. This gives a good bond for the next course.

After the forms are filled with concrete, place the scaffolding, and arrange the form-lifting device, as shown in Figs. 9 and 10.

Form-lifting Device.—This consists of two pairs of 3″ x 6″ posts with a lever working between each pair. The 3″ x 6″ pieces can be bought in 12- or 16-foot lengths, and they can be made as long as desired by splicing them together on three sides with 2-inch strips (see Fig. 14). Joints in a pair should be broken at least 3 feet. The pairs of 3″ x 6″ should not be placed directly in line. This allows the levers to work past each other as shown in Fig. 10. For a 10-foot silo they should be about 5 feet apart. Increase this distance by 6 inches for every foot increase in the diameter of silos over 10 feet.

These posts will be heavily loaded while the forms are being lifted, and should be erected as follows:

Lay two pieces of 2″ x 12″ planks across the floor of the silo on the line of the posts, taking a 12-foot and a 16-foot post to make up a pair. This prevents the splices from coming opposite each other. Place the posts in position, temporarily bracing them to the barn, if near enough, or to stakes in the ground outside the silo. While this bracing is only temporary for the first 3-foot course, it must be secure, and should be fastened to the post about 10 feet from the bottom.

Securely fasten the lower ends of the posts with cleats to the 2″ x 12″ plank under them. Next place the 2″ x 8″ x 12′ lifting planks in place as shown in Figs. 9 and 10, and wire them securely at the four points where they each cross the forms, so as to allow about a 2-inch space between them and the forms, when the wire is drawn tight. Use the size of wire given in Table E.

* See foot-note on page 15 regarding Bulletin 20.

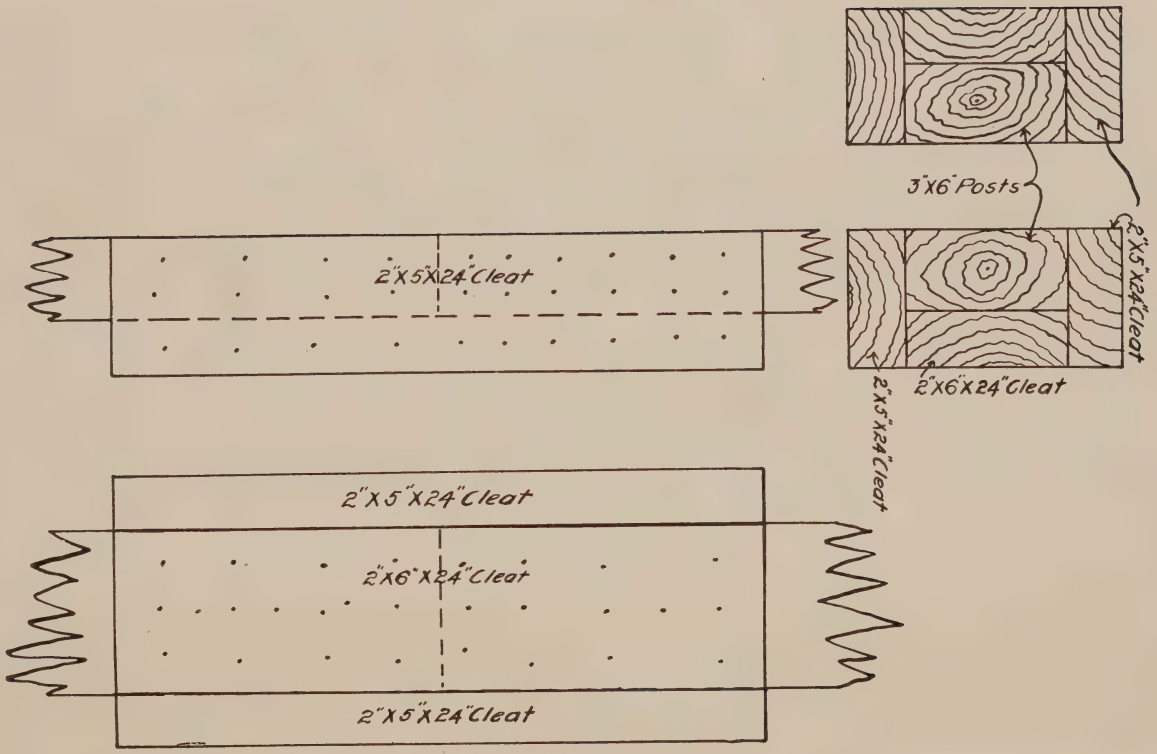


FIG. 14.—Method of splicing posts.

For the first lifting, wire the 2″ x 8″ lifting planks to the top circle of 2″ x 6″ pieces, as the bottom circle of 2″ x 6″ pieces rests on the concrete floor. Before making the second shift of forms, wire together the top and bottom circles of 2″ x 6″ pieces in both inner and outer form at the lifting point, so that the top circle will not have to take all the strain in lifting.

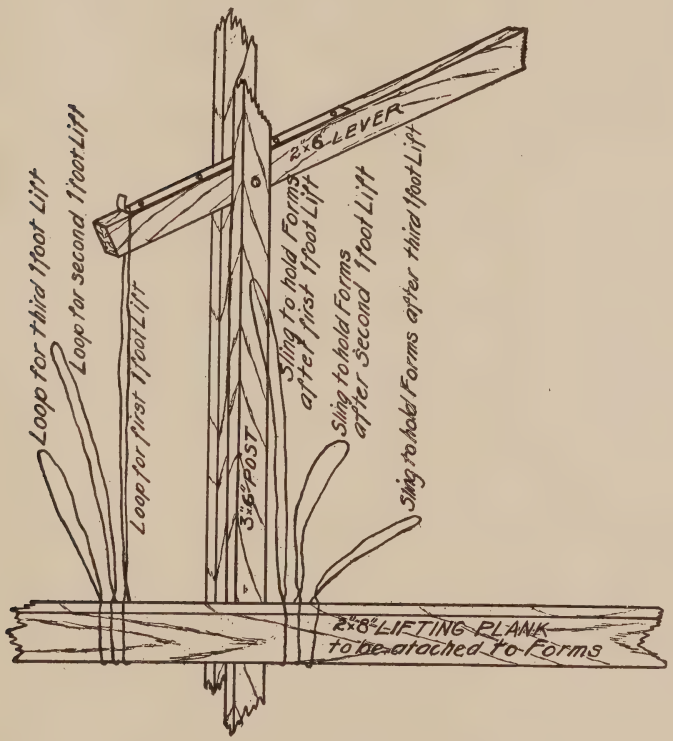

2"x6" LEVER
Loop for third 1 foot Lift
Loop for second 1 foot Lift
Loop for first 1 foot Lift
3"x6" POST
Sling to hold Forms after first 1 foot Lift
Sling to hold Forms after second 1 foot Lift
Sling to hold Forms after third 1 foot Lift
2"x8" LIFTING PLANK to be attached to Forms

Fig. 15.—Loops used in raising forms.

Measure on the posts 4 feet above the top edge of the 2″ x 8″ lifting pieces and bore $1\frac{1}{16}$″ to $1\frac{1}{8}$″ holes through the posts.

After the first lifting of the forms, these holes bored in the posts to receive the lever bolts should be spaced the height of one section apart. Thus, if the 36-inch forms lap the finished wall by 4 inches a section of wall 32 inches high is built with each setting of the forms.

and the holes should be spaced exactly 32 inches, center to center. Space these holes carefully, as the wires to be described later will not be changed for the rest of the lifts.

Place the levers, made as shown in Figs. 9 and 10, between the posts and use a 1-inch bolt, 15 inches long, to fasten each lever between a pair of posts.

As the levers will only raise the forms one foot at a time, three holds have to be provided in order to raise the forms three feet. This is done by making three loops of wire, each one foot shorter than the other, by means of which the ends of the levers are attached to the lifting plank (see Fig. 15). The longest of the loops is just long enough to attach the lifting board to the lever, when the short end of the lever is in the lowest possible position, as shown in Fig. 10.

Three more loops of wire are attached to the lifting planks, just long enough to slip over the bolt in the uprights, and in this way hold the forms, until the end of the lever can be attached to the second loop.

The shortest wire should hold the form about one inch higher than is finally desired. With the form held on the third or shortest loop, place two 2″ x 8″ braces under the form. These two pieces of 2″ x 8″ plank should be measured and cut to fit against the silo wall when they are nailed across the 3″ x 6″ posts. Level these braces carefully and nail them to the posts at a point just 4 inches below the top of the finish concrete in the walls.

Lay a straight edge across the top of the forms before lifting, and make a mark on the posts 4 inches below this edge. After the forms are raised, nail the two 2″ x 8″ braces to the posts, with the top edges at the mark. Brace the ends of the 2″ x 8″ planks with 1″ x 6″ boards, and further brace the posts whenever necessary as the work progresses, as shown in Fig. 10. With the weight of the forms on the levers, take off the loops over the bolt and lower the forms till the inside form rests on the 2″ x 8″ brace. Holding the levers in this position, expand the inside form into position with the adjusting bolts. Now lower the outside form in the same way, using the 6-inch spacing board to keep the two forms the correct distance apart at the top. Drive small wedges between the 2″ x 8″ x 12′ 0″ lifting pieces and the inside form so that the play in the wires between the 2″ x 8″ planks and the inside form will be taken up after the levers are released. These wedges will hold the 2″ x 8″ lifting pieces in place and they, in turn, hold the outside form. The levers can now be released, and the form is again ready for concrete.

TABLE E.

Diameter of Silo in Feet.	Gauge of Wire for Slings—2 Strands to Each Sling.	Size of Lifting Piece.	Size of Horizontal Braces Under Form.†	Size of Lever. (Total Length over all is given.)
	Gauge No.*			
10	10	2″x 8″x12′0″	2″x 8″x 8′6″	2″x6″x 7′6″
11	9	2″x10″x12′0″	2″x 8″x 9′0″	2″x6″x 8′6″
12	9	2″x10″x12′0″	2″x 8″x 9′6″	2″x6″x 9′0″
13	9	2″x12″x12′0″	2″x 8″x10′0″	2″x6″x 9′6″
14	8	2″x12″x12′0″	2″x10″x10′6″	2″x6″x 9′6″
15	8	2″x12″x14′0″	2″x10″x11′0″	2″x6″x10′0″
16	8	2″x12″x14′0″	2″x10″x11′0″	2″x6″x10′6″
17	8	2″x10″x14′0″	2″x10″x11′6″	2″x6″x10′6″
18	8	2″x10″x14′0″	2″x12″x12′0″	2″x6″x11′0″
19	7	2″x10″x16′0″	2″x12″x12′6″	2″x6″x11′6″
20	7	2″x10″x16′0″	2″x12″x13′0″	2″x6″x11′6″

Cautions.—As the work goes up, be sure to brace the 3″ x 6″ posts securely. They will carry the weight of the forms easily enough, but not without proper bracing.

Do not raise the forms above the finished wall, as trouble will be experienced in getting them back in place.

Be careful to raise the forms slowly and to work both levers at the same time in raising, so that the forms will be raised without binding.

Mix only two bag batches at a time, and place the whole batch before starting a new one.

Back-fill.—After the first three or four courses are placed, dirt should be filled in the hole next the concrete wall, and carefully tamped, leaving the ground next to the silo wall a little higher than the surrounding ground.

Handling the Concrete.

After the 3-foot form has been used three times and is set in place for the fourth time, the top of the form will be 8 feet above the ground outside the silo, and too high to shovel into. Therefore, some method of hoisting the concrete must be used. The easiest way is to hoist the concrete in galvanized iron buckets or coal-scuttles. For the fourth course, the buckets can be handed up, but above that point they must be hoisted by a rope. For quick work it is best to rig up a block and fall and use a horse to do the hoisting, raising 3 or 4 buckets at one

* American Steel and Wire Co.'s wire gauge used.

† The lengths of the braces in this column are only approximated for ordering lumber, and may be slightly varied.

time. The block can be made fast to a 2″ x 10″ plank temporarily nailed to the four parts, as far above the forms as necessary, and extending out over the outside of the silo on the side where the mixing is done. If a horse is used, sink a short post alongside the silo directly under the overhead block. Fasten another block to the post near the ground and pull through it to one side. A single line is all that is necessary, as four ordinary buckets full of concrete will only weigh about 200 pounds.

Caution.—In hoisting by horse or engine, as is sometimes done, the 3″ x 6″ posts must be well braced and guyed so that they will not be pulled out of plumb.

Mixing the Concrete.

The concrete in silo construction should be carefully mixed in accordance with the principles explained in Bulletin No. 2 Concrete should be mixed wet and the forms made tight to prevent the loss of any cement grout. Read Bulletin No. 2 carefully before starting the work on the silo, as this book explains fully the details of mixing and placing the concrete.

Footings and Floor.

The concrete in the footings and floor should be proportioned 1:3:6, which means:

1 part Portland cement;
3 parts sand;
6 parts gravel or broken stone.

Walls.

The concrete in the silo walls should be proportioned 1:2:4, which means:

1 part Portland cement;
2 parts sand;
4 parts gravel or broken stone.

Silo Doors.

In the description of the erection of the silo walls, no mention was made of the silo doors, openings for which must be left in the concrete walls. Fig. 16 is a vertical section through the silo, showing the ar-

* Bulletin 20, "How to Mix and Place Concrete by Hand," see foot-note, page 15.

rangement of the silo doors. The doors are 2 feet by 2 feet and are spaced 3 feet apart starting at 1 foot above the ground-line. The number of doors can, of course, be increased or diminished at the will

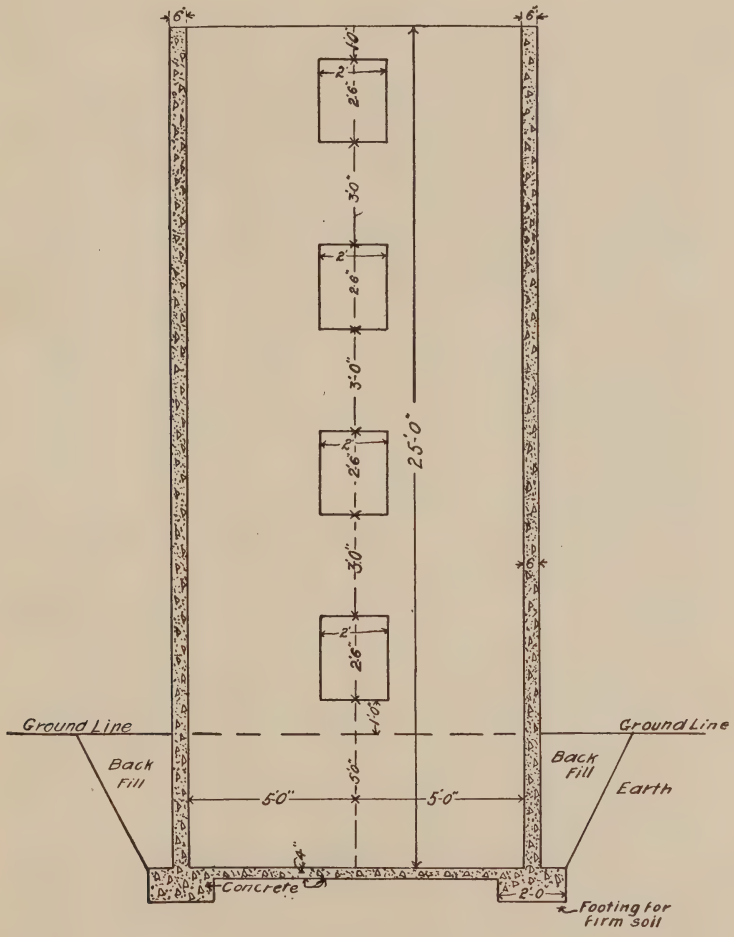
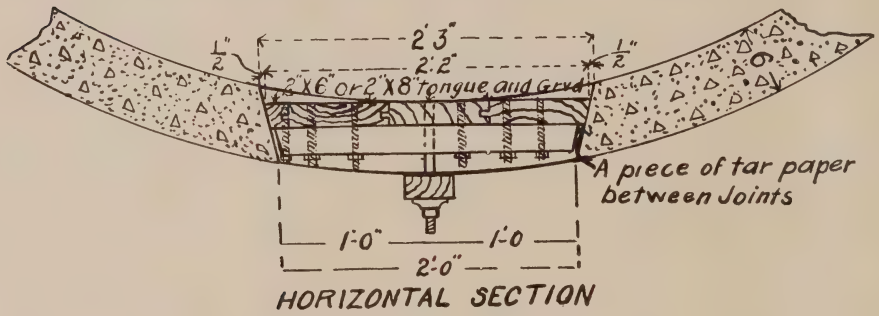


Fig. 16.—Vertical section of silo showing spacing of doors.

of the builder. Place these doors on the side of the silo nearest the feeding troughs.

Fig. 17 shows the construction of the silo door, with details. Make

the doors of planed 2″ x 6″ or 2″ x 8″ tongued and grooved boards, held together by two 2″ x 4″ cleats, to which they are bolted with $\frac{5}{8}$-inch bolts having round heads. The edges are all beveled $\frac{1}{2}$ inch,



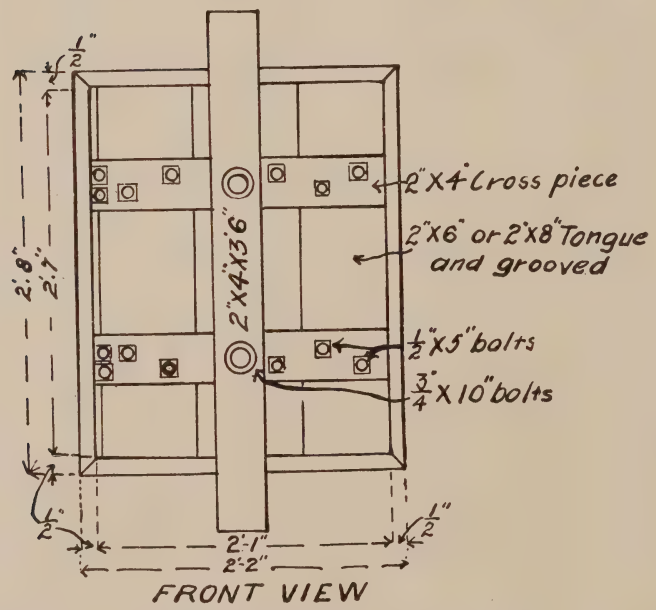


Fig. 17.—Silo door.

as shown in Fig. 17. The doors are held in place by two $\frac{3}{4}$-inch round-headed bolts which pass through a 2″ x 4″ x 3′6″ piece placed vertically on the outside of the silo wall. A gasket of tar-paper or similar

substance is used between the wood door and the beveled sides of the opening in the concrete, and by drawing up the bolts securely the door can be made absolutely air-tight. Care, however, must be used in planing the bevel edge of the doors in order to make a good fit.

FIG. 18.—Silo with continuous door opening.

The lumber used for the doors should be the most durable wood obtainable and should be planed on all sides. Fig. 17 is the same for all sizes of silos.

Fig. 18 shows a silo with continuous door openings, where tongued and grooved planks are used for doors, depending upon the pressure

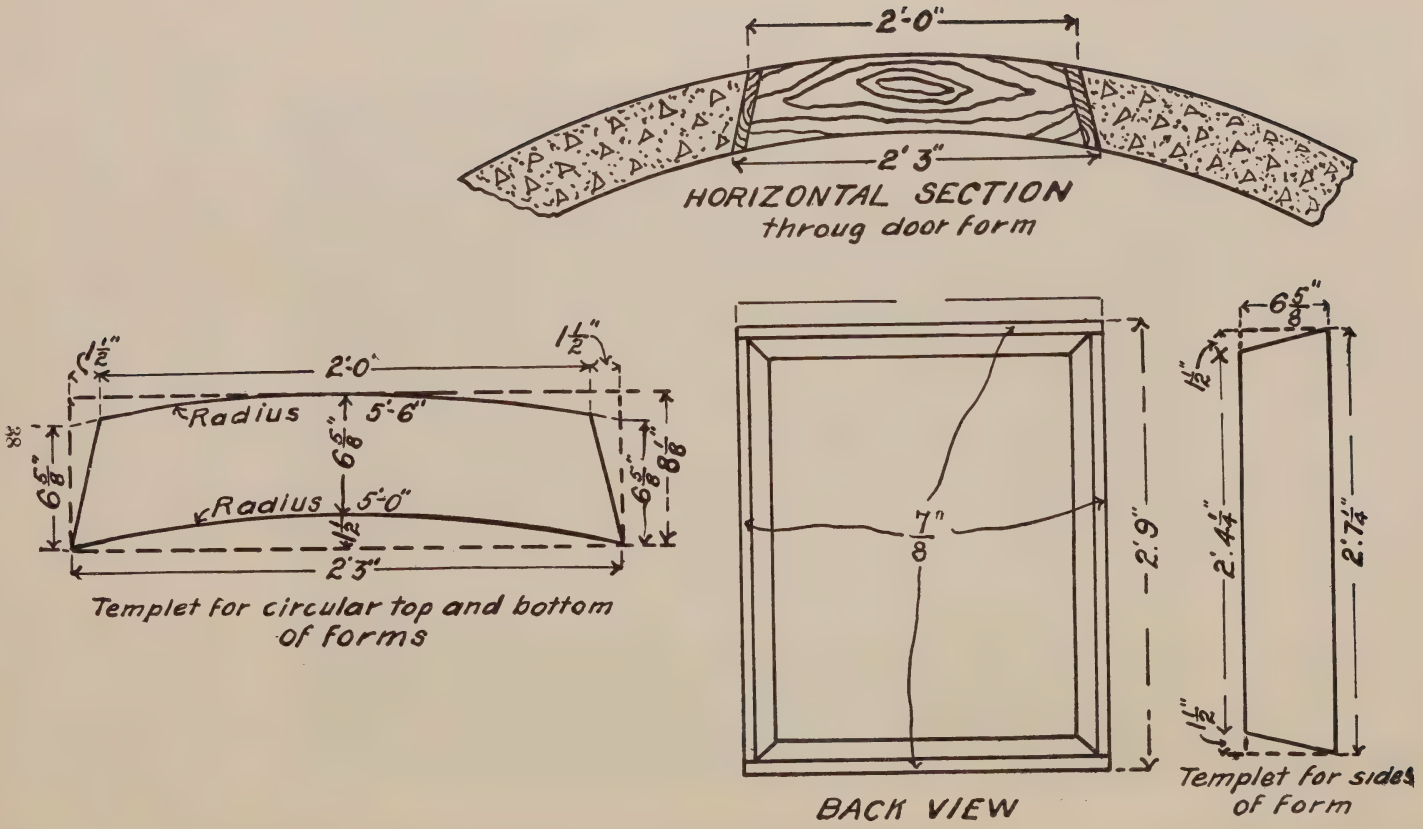


FIG. 19.—Form for making door openings.

of the silage to keep them in place. The view is taken from the inside of the silo.

Fig. 19 shows the form to be used to make the openings in the walls for the doors. It consists of a box open on the front and back, having straight sides and a curved top and bottom so that it will just fit between the silo forms. All the sides are beveled. To make this box form for the openings, use green $\frac{7}{8}$-inch boards planed on all sides. Cut two pieces according to each templet shown in Fig. 19. The dotted lines show the size of $\frac{7}{8}$-inch piece to be used. With the pieces cut as shown, nail them together with the sides in between the top and bottom pieces as shown in the "back view," Fig. 19. The inside edge all around the back of the box must now be planed down until flush with the outside edge, as the nailing of the four sides together on a bevel has made this inside edge stick out slightly. The box is ready for use as soon as it is cross-braced on the inside, so that it will keep its shape. To place the door opening form inside the silo forms, bring the concrete up to about 1 inch higher than the level for the bottom of the opening. Have the concrete very soft with an inch or so of mortar on top where the opening is to come. Shove the box form down into the concrete until it is at the right height and concrete around it, carefully spading the concrete along the sides of the box. A good plan is to mix up a little 1 to 2 mortar (1 part Portland cement, 2 parts sand) and keep placing it next to the box form as the concrete is placed. 1 to 2 mortar should always be placed about $\frac{1}{2}$ to $\frac{3}{4}$ inch thick over the top of the box form. On account of the spacing of the doors, the opening will not always come all in one 3-foot height of silo forms. In this case leave the box form in place and raise the silo forms as if it were not there. Care should be taken in this case to clean away the old mortar from the sides of the box above the form in order to make a good bond at this point.

There must be two of these box forms made, and each should be left in place until absolutely needed again, as this allows the concrete over the opening to harden before the box is removed. Before using, these boxes should be carefully painted with a couple of thin coats of black or cylinder oil. They should be wiped off before using, and when not in use should be kept out of the sun, to prevent warping.

Fig. 19 is the same for silos of all diameters, except that the curved top and bottom must fit the silo wall forms exactly. The side-pieces must always be $6\frac{5}{8}$ inches wide for a 6-inch wall, as shown, for the $\frac{5}{8}$-inch is lost in the bevel.

Ladder.

The ladder up the side of the silo alongside the doors can be made in many ways. We suggest the method shown in Fig. 20.

Bend round bars into the shape shown in Fig. 20 and place them into

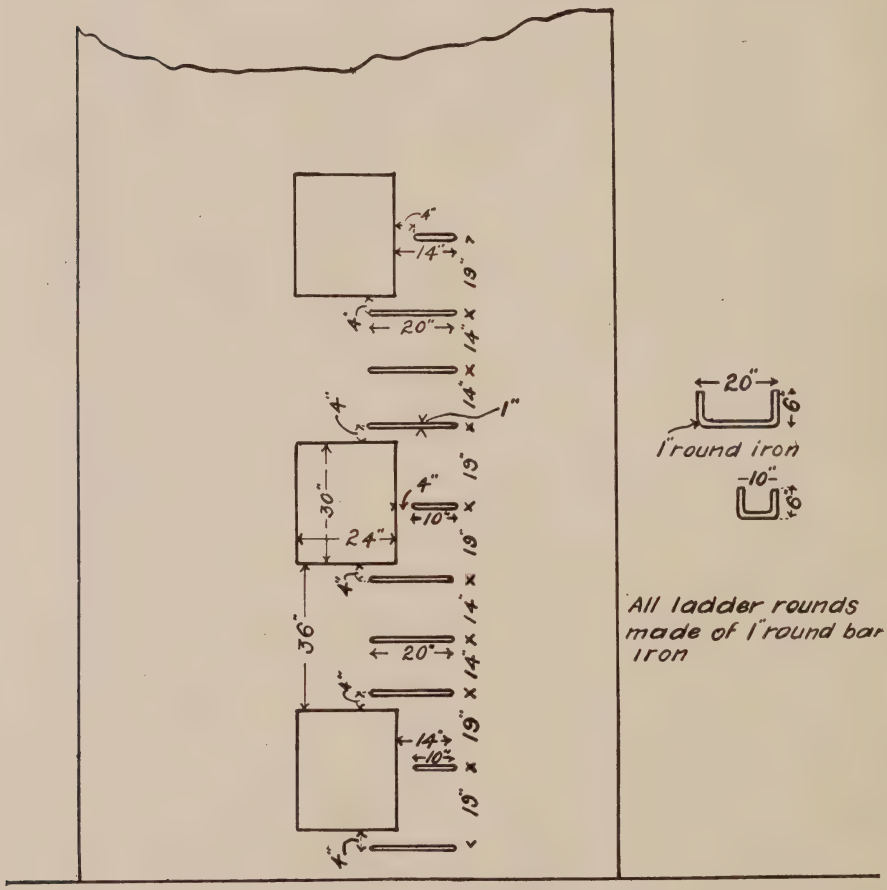


Fig. 20.—Spacing for ladder.

holes in the concrete, afterward filling any space around the bars with cement mortar.

The holes in the concrete can be formed by wedging a tapered wooden plug, slightly larger than the round iron, across the forms, in the position where you wish the hole to come (see Fig. 21). If the

plug be well oiled, it can be driven out, but if it sticks to the concrete, it can be burned out with a hot iron.

Fig. 20 gives the best spacing for the ladder, and plugs can be placed properly by measuring from the openings. Be careful not to get the holes nearer than 4 inches to the openings.

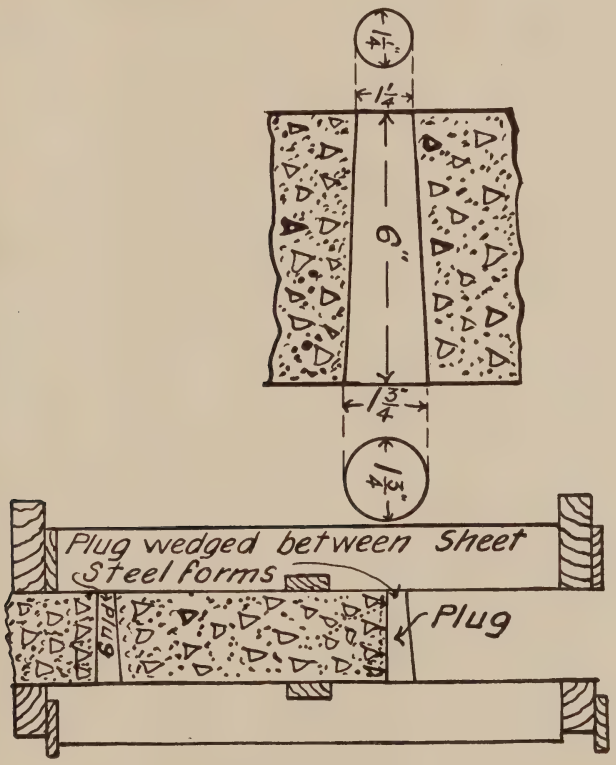


Fig. 21.—Plug to make holes for ladder.

Chute.

In many localities it is found most convenient to have a chute surrounding the silo doors. Fig. 22 shows a horizontal section of a simple design for making a wooden chute. The chute is attached to the silo walls by bolting a vertical 2″ x 4″ plank running the whole height of the silo on either side of the silo doors. The holes in the concrete are made by means of plugs 6 inches long in exactly the same manner as

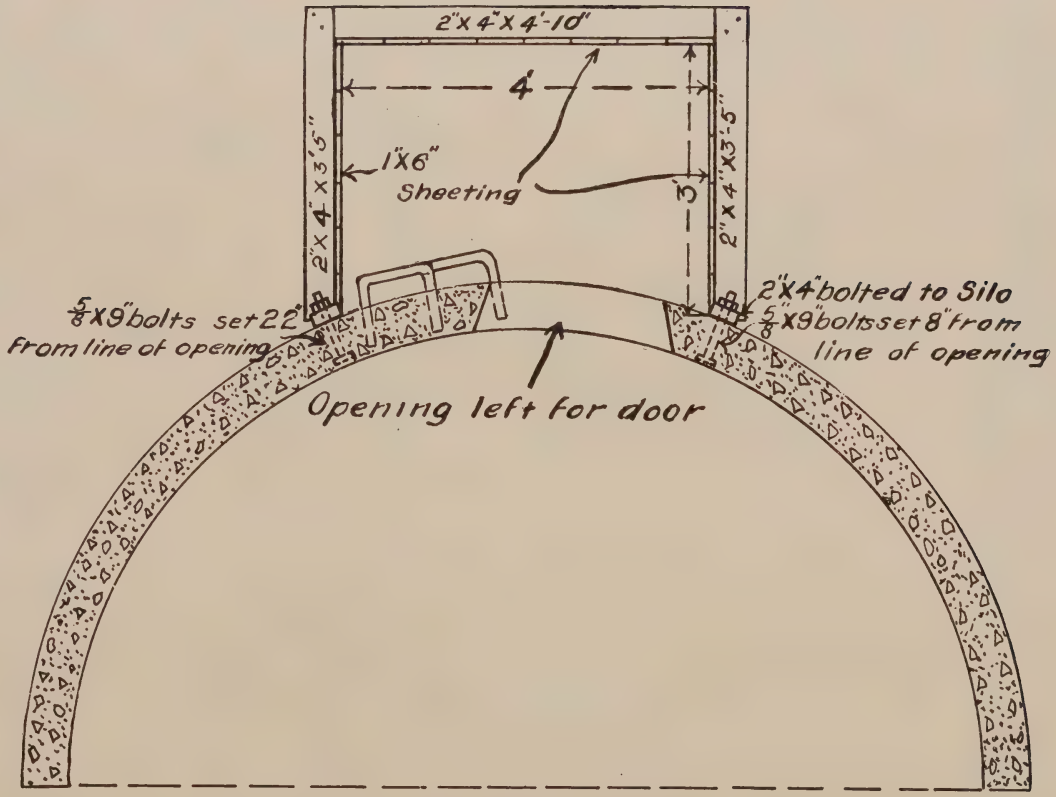

2"x4"x4'-10"
4'
1"x6"
Sheeting
3'
2"x4"x3'-5"
2"x4"x3'-5"
5/8"x9"bolts set 22"
from line of opening
2"x4" bolted to Silo
5/8"x9"bolts set 8" from
line of opening
Opening left for door

FIG. 22.—Chute.

described for the ladder irons, and are placed about every 3 feet in height. The $\frac{5}{8}$-inch bolts are placed from the inside and driven into the concrete until the head of the bolt is embedded in the wall. This must be done before the concrete hardens. The hole is then plastered up on both sides. If the holes for the ladder or chute are not in the

FIG. 23.—Concrete chute between two silos.

proper position, the plugs which are out of line should be driven out and the holes filled with cement mortar. Holes in the proper position can then be drilled in the concrete. A 2″ x 4″ frame is then nailed to the 2″ x 4″ uprights and the 1″ x 6″ sheeting placed on the inside to give the chute a smooth surface.

Chutes are sometimes made of concrete. Fig. 23 shows two concrete silos, with a concrete chute between. Where a roof is placed over the chute, it is well to have one or two windows in it.

Reinforcements.

The correct reinforcing of the silo walls with small steel bars or steel wire must be done with accuracy and care, as the strength of the silo depends on the correct use of steel in the walls. The silo walls are reinforced in two directions—vertically, to prevent failure due to wind pressures, and horizontally, to prevent failure due to the pressure of the silage. Silage is a heavy material and is estimated by the various State experimental stations to exert a side pressure of 11 lbs. per square foot for every foot in depth. It is on the basis of this estimate that all the calculations in Tables F and G are based. The vertical reinforcement consists of tie rods running from the top of the walls down into the footing. The horizontal reinforcements are hoops. There are many kinds of patented reinforcing bars, but these offer no great advantage over plain round bars or wire for silo reinforcement.

Tables F and G show the spacing for the reinforcement when using several different sizes of steel wire, and also for ⅜-inch steel bars, for any size of silo.

TABLE F.

Height of Silo in Feet.	Size and Spacing of Vertical Reinforcement.														
	For Silos 10′ to 13′ Inside Diameter.					For Silos 14′ to 17′ Inside Diameter.					For Silos 18′ to 20′ Inside Diameter.				
	Spacing in Inches for ⅜″ Mild Steel Bars and Number of Bars Used.	Spacing in Inches and Number of Strands Used for Different Gauges of Steel Wire.				Spacing in Inches for ⅜″ Mild Steel Bars and Number of Bars Used.	Spacing in Inches and Number of Strands Used for Different Gauges of Steel Wire.				Spacing in Inches for ⅜″ Mild Steel Bars and Number of Bars Used.	Spacing in Inches and Number of Strands Used for Different Gauges of Steel Wire.			
		Gauge. No. 000.	Gauge No. 2.	Gauge No. 5.	Gauge No. 8.		Gauge No. 000.	Gauge No. 2.	Gauge No. 5.	Gauge No. 8.		Gauge No. 000.	Gauge No. 2.	Gauge No. 5.	Gauge No. 8.
25′ and under . .	1-30″	1-36″	1-19″	3-36″	3-22″	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
25′ to 30′ .	1-19″	1-24″	2-25″	3-23″	6-28″	1-25″	1-30″	2-33″	3-31″	6-36″	. .	. .	. .	. .	. .
30′ to 35′ .	2-26″	1-16″	3-26″	6-32″	9-29″	1-18″	1-24″	2-24″	3-22″	6-28″	. .	. .	. .	. .	. .
35′ to 40′ .	2-19″	2-24″	3-18″	6-23″	12-28″	2-27″	1-16″	3-26″	6-32″	9-30″	1-17″	1-21″	2-22″	3-21″	6-26″

Note: American Steel and Wire Co.'s gauges used.

⅜″ bars are round, ⅜″ in diameter.

No figures are given for silo 18′ to 20′ in diameter less than 35 feet height, or silo 14′ to 17′ in diameter less than 25 feet high, as these are not good proportions for silos.

Referring to Table F, the vertical or upright reinforcing necessary for a 10-foot silo, 25 feet high, is found to be one $\frac{3}{8}$-inch rod, running from top to bottom every 30 inches around the silo:

or 1 strand	wire	gauge	000,	spaced	every	36	inches
or 1	"	"	"	2,	"	"	19	"
or 3 strands	"	"	"	5,	"	"	36	"
or 3	"	"	"	8,	"	"	22	"

Several choices are given, so that the reinforcement may be bought from stock.

TABLE G.

SIZE AND SPACING OF HORIZONTAL REINFORCEMENT AROUND SILO.

Distance in Feet Measured from Top of Silo.	For Silos 10′ to 13′ Inside Diameter.					For Silos 14′ to 17′ Inside Diameter.					For Silos 18′ to 20′ Inside Diameter.				
	Spacing in Inches for $\frac{3}{8}$″ Mild Steel Bars and Number of Bars Used.	Spacing in Inches and Number of Strands Used for Different Gauges of Steel Wire.				Spacing in Inches for $\frac{3}{8}$″ Mild Steel Bars and Number of Bars Used.	Spacing in Inches and Number of Strands Used for Different Gauges of Steel Wire.				Spacing in Inches for $\frac{3}{8}$″ Mild Steel Bars and Number of Bars Used.	Spacing in Inches and Number of Strands Used for Different Gauges of Steel Wire.			
		Gauge * No. 000.	Gauge * No. 2.	Gauge * No. 5.	Gauge * No. 8.		Gauge * No. 000.	Gauge * No. 2.	Gauge * No. 5.	Gauge * No. 8.		Gauge * No. 000.	Gauge * No. 2.	Gauge * No. 5.	Gauge * No. 8.
0′ to 5′	1-18″	1-18″	1-18″	1-16″	1-12″	1-18″	1-18″	1-18″	1-12″	1-11″	1-18″	1-18″	1-18″	1-12″	1-9″
5′ to 10′	1-18″	1-18″	1-16″	1-11″	1-7″	1-18″	1-18″	1-14″	1-9″	1-5″	1-18″	1-18″	1-12″	1-7″	2-9″
10′ to 15′	1-15″	1-18″	1-12″	1-7½″	2-9″	1-14″	1-16″	1-9″	1-6″	2-7″	1-12″	1-15″	1-8″	2-9½″	3-9″
15′ to 20′	1-14″	1-17″	1-9″	1-6″	3-10″	1-11″	1-12″	1-7″	2-8½″	3-8″	1-9″	1-11″	1-6″	2-7½″	3-6½″
20′ to 25′	1-11″	1-14″	1-7″	2-9″	3-8″	1-9″	1-10″	1-5½″	2-7″	3-6″	1-7″	1-9″	1-4½″	3-8½″	3-5½″
25′ to 30′	1-9″	1-11″	1-6″	2-7½″	3-7″	1-7″	1-8″	1-4½″	2-5½″	3-5″	1-6″	1-7″	1-4″	3-7½″	3-4½″
30′ to 35′	1-8″	1-10″	1-5″	2-6½″	3-6″	1-6″	1-7″	1-4″	3-7½″	3-4½″	1-5″	1-6″	1-3½″	3-6″	3-4″
35′ to 40′	1-7″	1-8″	1-4½″	2-5½″	3-5″	1-5″	1-6″	1-3½″	3-6½″	3-4″	1-4½″	1-5″	1-3″	3-5½″	3-3½″

* American Steel and Wire Co.'s gauge $\frac{3}{8}$″ inch bars are round, $\frac{3}{8}$ inches in diameter.

Table G shows the horizontal or "hoop" reinforcement around the silo and the vertical distance it is to be spaced apart in the silo walls. Since the pressure in a silo increases with the depth, it is necessary to make the walls much stronger at the bottom than at the top. The silo walls are divided into 5-foot horizontal sections up to 40 feet in height and the distance in inches between the bars or wires is given for each section, as well as the number of strands of wire to be placed at one time. Thus, in the 10′ x 25′ silo being described, if No. 5 gauge wire were purchased, it would require from the top of the silo down 5 feet, one strand of No. 5 wire every 16 inches in depth. For the section of wall between 5 and 10 feet from the top, one strand of No. 5 wire should be placed every 11 inches in depth. For the section

between 10 and 15 feet from the top, one strand of No. 5 wire should be placed every $7\frac{1}{2}$ inches in depth. For the section between 15 and 20 feet from the top, one strand of No. 5 wire should be placed every 6 inches in depth. For the section 20 to 25 feet down, or, as the silo is only 25 feet in height, for the bottom 5-foot section, two strands of the No. 5 wire are placed every 9 inches, making this part of the silo wall the strongest of all. The same amount of reinforcement is always necessary for sections of walls of equal distance from the top of the silo, in all silos of the same diameter, regardless of the total height.

The same gauges of wire are figured in Tables F and G, so that only one size of wire may be used for all the reinforcement, although it will be slightly cheaper to order the heavier gauges for the lower sections of the silo and the vertical reinforcement and the lighter gauges for the top sections.

In no case should the horizontal wires or bars be placed over 18 inches apart or the vertical bars or wires placed over 36 inches apart.

TABLE H.

Number of Gauge of Wire.*	Diameters.		Sectional Area in Sq. Inches.	Weight in Pounds per Foot.	Length in Feet per Pound
	Fraction of inch.	Decimals of inch			
000	$\frac{3}{8}$	.3625	.103210	.3505	2.853
2	$\frac{1}{4}$	.2625	.054119	1.838	5.441
5	$\frac{3}{16}$	.2070	.033654	.1143	8.750
8	$\frac{1}{16}$	.1620	.020612	.0700	14.290
Steel bars..	$\frac{3}{8}$	..	.1104	.375	..
	$\frac{1}{2}$	..	.1960	.668	..
	$\frac{5}{8}$	..	.3070	1.044	..

Table H shows the different sizes of the wire gauges used. From it the weights and length of wire or steel bars can be figured.

How to Place Steel Reinforcement.

The placing of the reinforcement is a very simple matter, but there are several points of importance to be noted.

1. To tie reinforcement to prevent slipping. The horizontal reinforcement should be cut in one length, if wire, and the ends looped together and twisted back. If bars are used, the ends should be bent

* *Note:* American Steel and Wire Co's. gauge. All fractions of an inch for wire figured to the nearest $\frac{1}{64}$th.

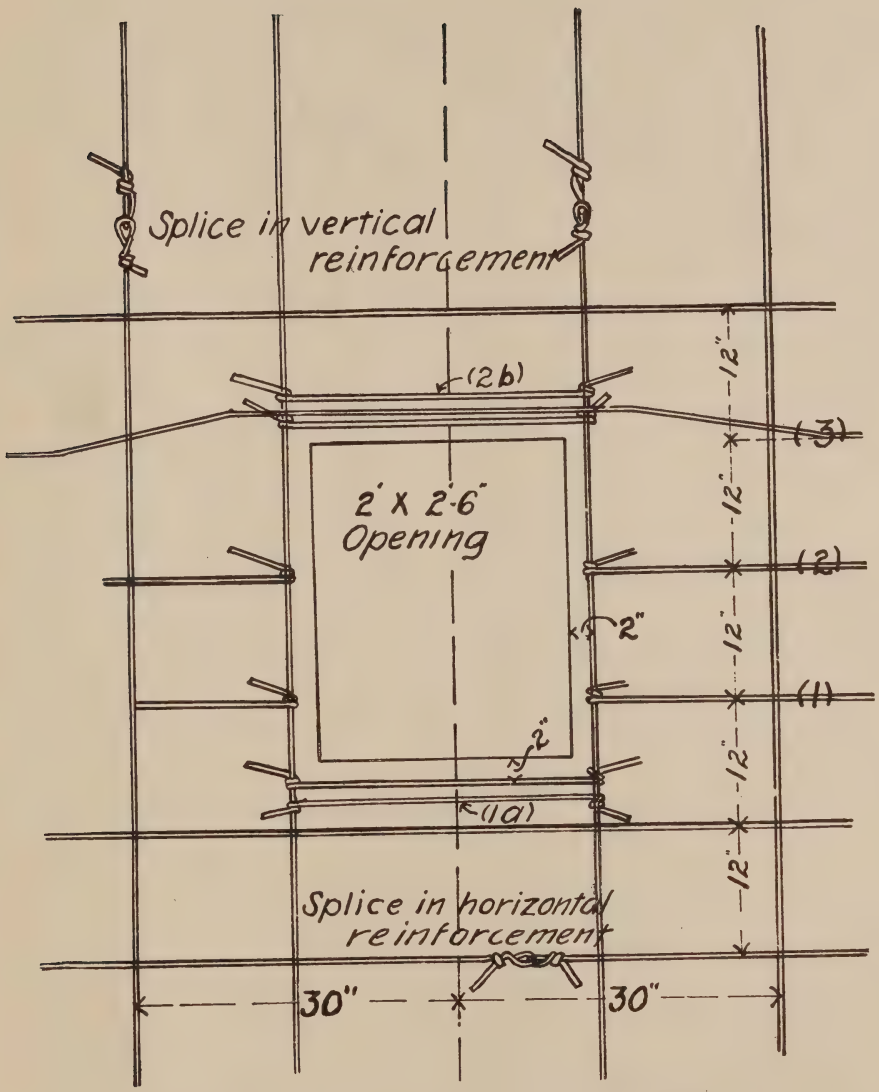


FIG. 24.—Position of reinforcement around door opening

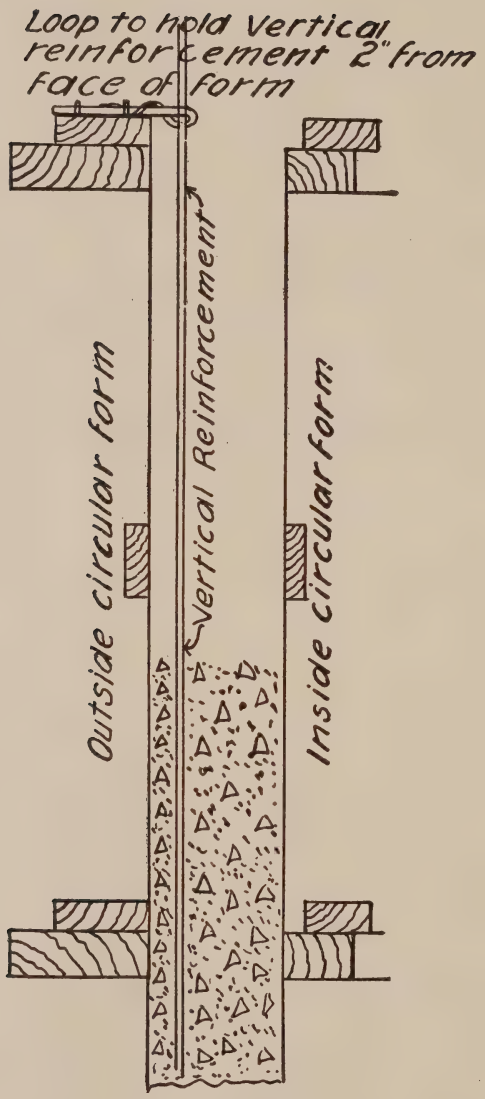

Loop to hold vertical reinforcement 2" from face of form
Vertical Reinforcement
Outside circular form
Inside circular form

FIG. 25.—Loop to hold vertical reinforcement in correct position while placing concrete.

around each other at each lap. The extreme ends of the vertical reinforcement should be tied by bending around four extra strands of the largest wire used, two wires being placed 2 inches below the top of the silo wall, and the other two in the center of the silo footings.

The vertical rods should be placed in short lengths, as it is very hard to handle the forms with rods running the entire height of the silo. These short lengths can be twisted or spliced together, as the wall is built up.

In starting the vertical reinforcement in the footing use only 2′ 6″ or 3′ 0″ lengths, taking six inches to twist around the two horizontal tie rods or wires placed in the center of the footings. This will leave 1′ 6″ to 2′ 0″ to stick above the finished footings.

The next section of vertical reinforcement is tied to these short lengths, and they will not interfere with the setting of the concrete forms.

2. To place reinforcement around doors and openings.

Fig. 24 shows how the reinforcement is placed around the door openings. In the section of wall used the horizontal reinforcement is placed 12 inches apart and the vertical 36 inches apart. The dotted line about the middle of the opening shows where the vertical wire would have come. As it is desired to always have a vertical rod or wire not over 3 inches away and on either side of the line of doors, two verticals have to be substituted for the one omitted. Where the horizontal wires or bars numbered (1) and (2) in Fig. 24 would run across the opening some distance from the top or bottom, fasten them to the verticals next to the opening, as shown. Cut short pieces of wire and place them at (1a) and (2b) to take the place of (1) and (2) The horizontal short wire 2 inches above and below the opening is always placed regardless of where the horizontal reinforcement comes. Wire marked (3) comes near enough to the top of the opening to be bent up and over it without cutting and using an extra short piece. In order to hold the rods in place, bend a piece of wire as shown in Fig. 25, and hook it over the outside of the form.

3. The horizontal hoop reinforcement should be on the outside of the vertical reinforcement and about 2 inches from the face of the outside form.

Roof over Silo.

A roof is essential to a good silo in order to keep the snow out and to prevent the silage from freezing. It helps the silage to hold its heat if proper attention is given to the closing of the silo doors during

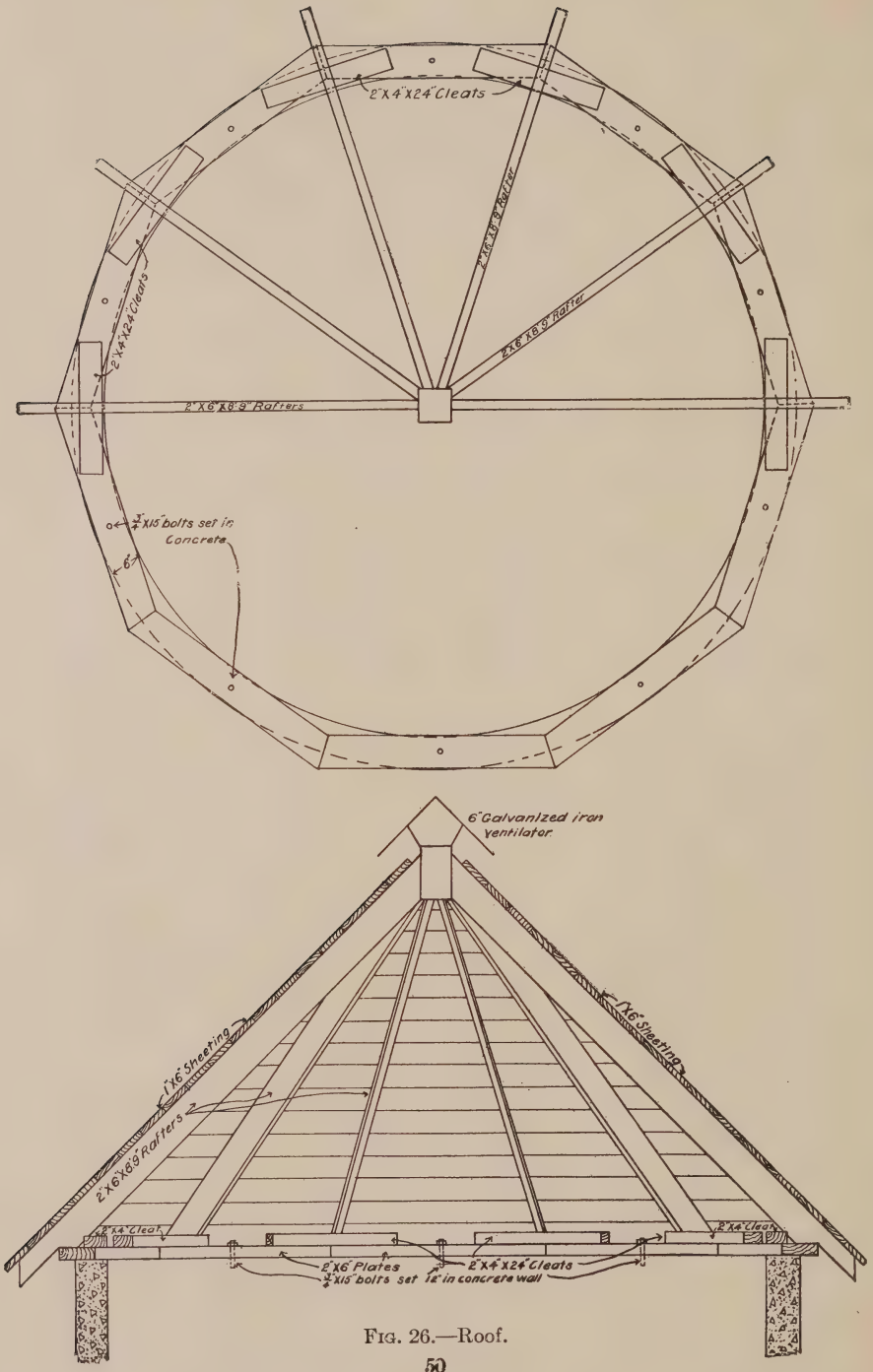

2"X4"X24" Cleats
2"X6"X8'-9" Rafter
2"X6"X8'-9" Rafter
2"X4"X24" Cleats
2"X6"X8'-9" Rafters
¾"X15" bolts set in Concrete
6"
6" Galvanized iron Ventilator
1"X6" Sheeting
2"X6"X8'-9" Rafters
1"X6" Sheeting
2"X4" Cleat
2"X4" Cleat
2"X6" Plates
¾"X15" bolts set 12" in concrete wall
2"X4"X24" Cleats

FIG. 26.—Roof.

cold weather. Fig. 26 shows how a cheap, substantial roof can be built. Set $\frac{3}{4}$″ x 15″ bolts 11 inches down into the form on the last filling so that they will stick out 4 inches above the top of the wall. The plate, which is made of 2″ x 6″ pieces cleated together, with 2″ x 4″ cleats, is held in place by these bolts. This plate can be laid out on the ground and the pieces cut and put together on top. Give enough

Fig. 27.—Hollow wall silos.

pitch to the roof to shed snow. The roof shown in Fig. 26 is pitched 45 degrees. This gives room for storing the silage several feet above the top of the wall and allows for its settlement after the final filling. It also gives enough room for a man to work during the filling. Build an ordinary trap-door between two of the 2″ x 6″ rafters on the side from which the silo is to be filled.

Fig. 26 shows no roofing over the 1″ x 6″ sheeting. Either shingles,

galvanized sheet-iron, or tin may be used. During cold weather stuff the opening between the roof and the roof plate full of old rags, paper, etc., to help prevent freezing.

Fig. 27 shows the two silos of Professor Frank H. Hall, Illinois Farmers' Institute, one having a shingle and the other a concrete roof. They are 34 feet 6 inches high and 16 feet inside diameter, with a hollow wall, 5½ inches inside wall, 3½ inch continuous air-space, and 3-inch outside wall. The first was built in 1905, the second in 1908.

Ordering Materials.

For convenience in ordering materials we give the following blank "Bill of Materials," which can be filled in for any size of silo.

(Duplicate of this Bill of Materials will be found on page 67.)

BILL OF MATERIALS FOR CONCRETE SILO.

Size of Silo.... ft. x .... ft. inside measurement.

CONCRETE MATERIALS:

..... bbls. of Portland Cement.
..... cu. yds. Sand.
..... " " Gravel (or stone).

REINFORCEMENT:

..... lbs. steel wire No.....gauge.
..... " " " " ..... "

or

..... lbs. round Bars, Size.....inches in diameter.
..... " " " " .....inches " "

LUMBER.

Forms.

..... lineal ft. 1″ x 3″ = ...B.M.
..... " " 1″ x 4″ = ... "
..... " " 2″ x 4″ = ... "
..... " " 2″ x 6″ = ... "

Scaffolding and Bracing.

..... lineal ft. 1″ x 6″ = ...B.M.
..... " " 2″ x 6″ = ... "
..... " " 2″ x 8″ = ... "
..... " " 2″ x 10″ = ... "
..... " " 2″ x 12″ = ... "
..... " " 3″ x 6″ = ... "

Roof.

..... lineal ft. 1″ x 6″ = ...B.M.
..... " " 2″ x 4″ = ... "
..... " " 2″ x 6″ = ... "

Chute.

..... lineal ft. 1″ x 6″ = ...B.M.
..... " " 2″ x 4″ = ... "

Doors.

..... lineal ft. 2″ x 6″, or 2″ x 8″ Tongued and Grooved and Surfaced = ...B.M.
..... lineal ft. 2″ x 4″ = ... "
Total = ... "

Sheet Metal for Forms (and Roof).

..... Sq. ft. 24 Gauge Sheet Steel @ .94 lbs. per sq. ft. = ...lbs.

or

..... Sq. ft. 24 Gauge Galvanized Sheet Steel @ .94 lbs. per sq. ft. = . .lbs.

Sundry Items.

Nails.
Bolts.
1-inch round iron for Ladder.
Waterproofing.
Shingles or other Roofing (if used).
Oil for painting forms.

Concrete Mixing Plant.

See Bulletin No. 20* for Tools and Materials necessary for mixing Concrete.

Patching.

If, on raising the forms open spaces between the stones are found, due to carelessness in spading or on account of a leak in the form, these places should be patched at once. First remove all the loose pebbles and rough up the surface to get a good bond. Then fill the hole with a 1 to 2 Portland cement mortar, making the outside flush with the rest of the surface. If patched at once and then painted later on with cement grout, the place will not be noticeable. Be careful not to let the patched place dry out more rapidly than the surrounding concrete. This can be prevented by wetting every day with water applied by means of a whitewash brush.

Painting the Silo.

As before explained, the inside of a silo should be as smooth as possible, to permit the silage to settle evenly.

As the wall is built, slight rough spots are sometimes left, due to concrete sticking to the forms. These can be easily made smooth by applying a coat of cement mortar, consisting of one part Portland cement and one part fine sand, mixed with water to the consistency of cream. Apply this with a whitewash brush. Before applying, brush the wall thoroughly with a dry, stiff brush. Then wet the wall, and then apply the wash, while the wall is still wet. Stir your cement and sand mixture constantly while applying. If this is not done, the cement and sand settle to the bottom, and you will be painting your wall with water only. Mix this grout in very small quantities and put on a thin and not a thick coat over both the inside and outside of the silo.

This treatment not only makes a smooth wall, but also tends to made it waterproof. There are a number of patented waterproofing

* See foot-note, page 15, for information regarding Bulletin No. 20.

compounds, which can be mixed with the cement grout, or with the concrete, but if the concrete is properly proportioned and placed, it will be waterproof in itself.

Another method of waterproofing, called the Sylvester process, consists in drying the walls thoroughly and cleaning with a wire brush.

FIG. 28.—Painting the silo.

Then paint with a hot solution consisting of three pounds of castile soap dissolved in four gallons of water. Use a kalsomine brush for the paint and do not boil the solution or let it froth while applying. After twenty-four hours' drying apply a second solution, consisting of a cold solution of ½ pound of alum to 4 gallons of water. This should make even poorly mixed and placed concrete air- and water-tight.

By using the form posts for scaffolding before taking down, the inside of the silo can be easily painted. The outside can be painted from a swinging scaffold, hung from the top.

While we have assumed that the painting will be done after the entire wall is built, each section, upon removing the forms, can be painted at once. This will not present quite as good an appearance as painting the whole silo at one time, but less care is required in preparing the surface to properly take the plaster.

Fig. 28 shows the silo of Dr. J. D. Hammond, Wheaton, Ill., built by the New Enterprise Concrete Machinery Co., of Chicago, Ill., in 1908. The photograph shows the hanging scaffold for painting the outside of the silo.

Hollow Wall Solid Concrete Silo.

A hollow wall concrete silo can be constructed in exactly the same way as described for the solid wall silo, with the following changes:

Forms.

Erect the forms with a 12-inch space between them instead of 6-inch.

Construct as many circular boxes 1½ feet long, 3 feet deep, and 4 inches thick, as are necessary to go around the wall. These boxes are used in pairs, the pairs being placed 4 inches apart in between the silo forms. The concrete is placed between the forms and the boxes, and not inside the boxes. This makes a 4-inch hollow space between the outer and inner walls. Fig. 29 shows the details of how these forms or boxes are built so they can be collapsed and taken out for each raising of the circular forms.

The top and bottom pieces are sawed on the proper circle from a 2-inch board, and are just 4 inches wide. They are then made into a frame by nailing three 1″ x 4″ x 2′ 8″ pieces on both sides, as shown in Fig. 28. The top and bottom 2 x 4's are then sawed on a bevel from end to end. The level in both top and bottom of the box slopes in the same direction.

This cuts the box in half when made, so that you have two boxes, 3 feet by 1½ feet by 2 inches, which, when fitted together, make the proper width of 4 inches.

The outside and one end of each half is covered with sheet metal, No. 24 gauge. The metal on the end of one half should lap the metal on the end of the other half by about two inches.

The metal is not nailed to the other end of either half, but is allowed to follow the curve of the form 3 inches beyond the end.

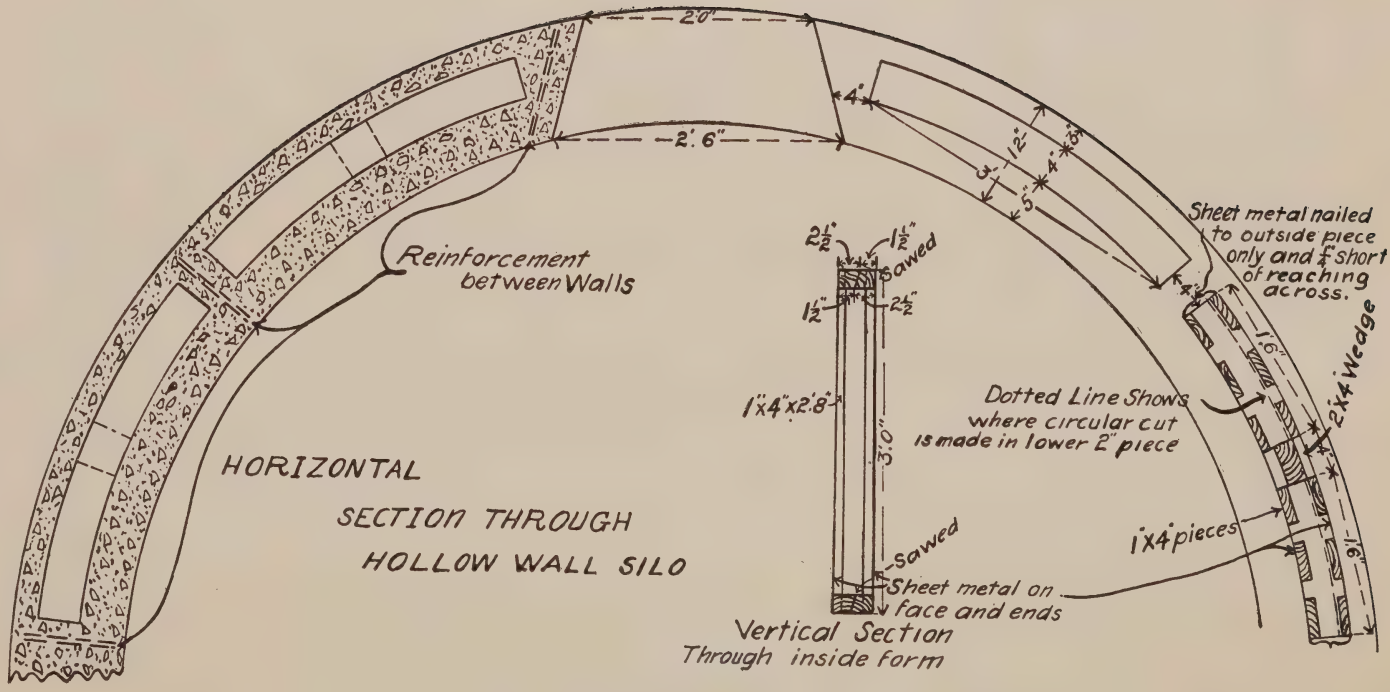


FIG. 29.—Section of hollow monolithic silo.

Two other boxes are made up in exactly the same way, and these four boxes fit together to make the completed form for the hollow air-space.

Placing the Boxes.

As the silage will not freeze below the ground-line, the hollow air-space need not be started until the forms are set for the third 3-foot course.

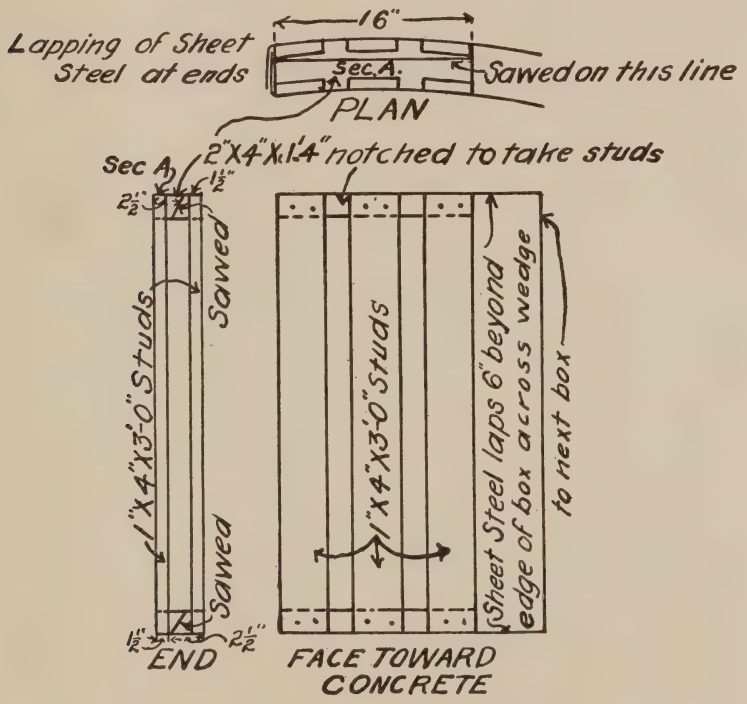


Fig. 30.—Detail of Boxes.

First set the outside and inside circular forms. Nail a piece of 1″ x 4″ temporarily along the top of each box, thus holding them together. (See Fig. 29.) Set the boxes in the form, using two, and placing them so the 3-inch laps of sheet metal at the ends come together. (See Fig. 30.) When the concrete is placed, the boxes will be forced together from the ends, unless wedges are placed near the bottom and at the top to hold them apart. Two 4-inch wedges should be used for this, and they should be large enough to hold the boxes 4 inches apart.

All the boxes for one 3-foot course of concrete should be placed at one time. They can be kept the proper distance from the circular forms by means of spacing boards, of the proper width, just as the circular forms themselves are kept apart.

Placing the Concrete.

Place the concrete around the boxes in the same way as described under solid wall construction.

Removing the Boxes.

As soon as the concrete is set sufficiently, collapse the boxes by removing the temporary 1 x 4, pulling out the wedges, and lifting out the boxes one half at a time. Pull out section marked A first (Fig. 30). Be sure that the sheet metal nailed across the two ends is at least $\frac{1}{4}$ inch short of reaching the outside face of the side to which it is *not* nailed. If it extends all the way across the end, it will bind.

Resetting the Boxes.

If each box form were placed directly over the opening made by the box form in the course below it, the silo walls would not have a continuous air-space, but a series of 3-foot 4-inch air-spaces running from top to bottom, with a 4-inch wall of concrete between them. To avoid this and make the air-space continuous, on moving up a course set each box half its length further around, so that the wedges in the middle will come directly over the solid 4-inch partition between the spaces in the course below.

Pieces of green plank 1 inch x 4 inches x 6 inches will have to be placed in the opening below each 4-inch space between the forms, before resetting. If this is not done, the concrete will run into the opening below the forms, as each 4-inch partition between the spaces comes over the middle of the space below. They are left in the wall of the silo.

Special small boxes may have to be made to go alongside the door openings. Do not allow any box to come within one foot of the door openings.

Before the concrete for the last foot of the wall is placed, remove the boxes and lay either strips of green well-soaked boards, or strips of sheet metal over the 4-inch opening; then fill in the last foot of concrete. This seals the air-space.

It is well to leave several holes through the inside wall, connecting the dead air-space with the inside of the silo. This can be done by using two or three wooden plugs and driving them out when the wall has set.

Patented Forms.

Several companies building silos have patented forms for forming the hollow air-spaces.

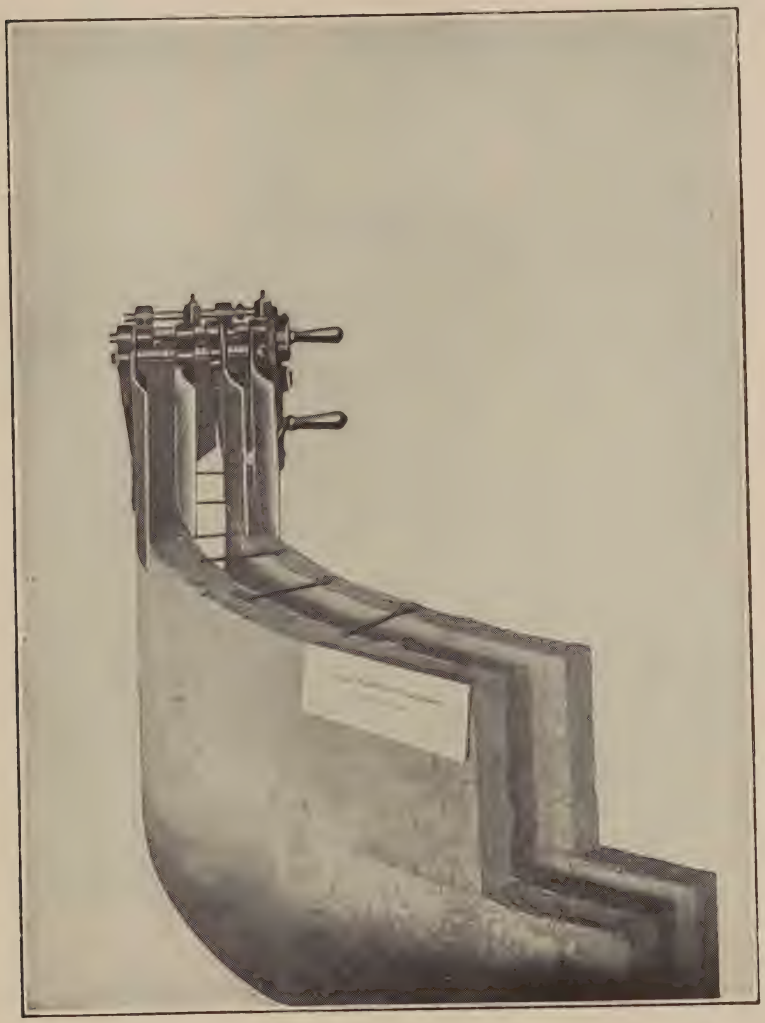


Fig. 31.—Patent forms for hollow silo walls.

Fig. 31 shows the patented construction forms used by the New Enterprise Concrete Machinery Co. They are collapsible steel forms.

The outer forms are reinforced with angle steel bars; the inner forms are of 14 gauge steel and are held in position by gauges and keys. By a simple turning of the keys the forms are loosened or tightened. Turning the key half-way around loosens the forms for removal or

Fig. 32.—Silo built with Ferroinclave reinforcement.

adjustment. The forms are $3\frac{1}{2}$ feet in height and have a variable circumference so that they can build a silo of any diameter.

These forms or machines are easily operated and common labor can do any part of the work in laying walls. No expert or high-priced mechanics are required. Note in this illustration the $\frac{3}{8}$-inch galvanized steel rods binding the two parts of the wall together.

Reinforcement.

Place the same amount of reinforcement given under the solid wall tables in the inner wall 4 inches from the inside face. Also reinforce the outside 3-inch wall with a strand of at least No. 2 gauge wire every 2 feet, both vertically and horizontally. Place short pieces of reinforcement wired to both wall reinforcement in the 4-inch partitions between the air-spaces. Also place pieces of reinforcement bent so that they will anchor the 12-inch finishing section on top to both outer and inner walls.

The roof, chute, doors, etc., can all be made in the same manner

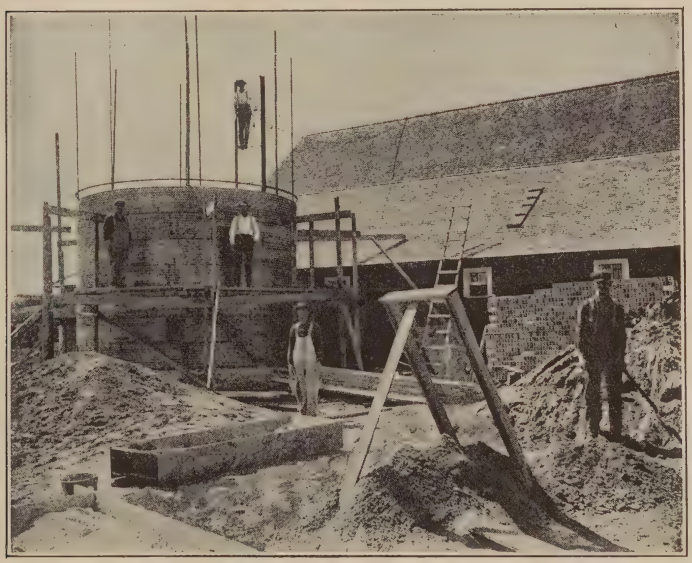


Fig. 33.—Silo being built using Ferroinclave reinforcement

as described in solid wall construction, except that the sizes will have to be increased to fit the greater circumference of the silo due to the thicker walls.

Patented Reinforcing.

There are a number of special forms of reinforcing made by manufacturers which present certain advantages over the ordinary kind. The American Steel and Wire Co., of Chicago, Ill., make a wire-mesh reinforcing, which comes in sheets or rolls, and from them can be

obtained a mesh, which will take the place of the plain vertical and horizontal wires described above. Care must be exercised in getting this class of reinforcement in the proper position in the concrete wall,

FIG. 34.—Concrete block silo.

and it is probably a little more difficult to handle. It has, however, the advantage of exactly spacing the horizontal and vertical reinforcing.

Fig. 32 shows a silo built with Ferroinclave reinforcing, manu-

factured by the Brown Hoisting Machinery Co., of Cleveland, Ohio. Fig. 33 shows the reinforcing in position, before the concrete is applied. The sheets are curved to the shape of the silo, and act as a form as well

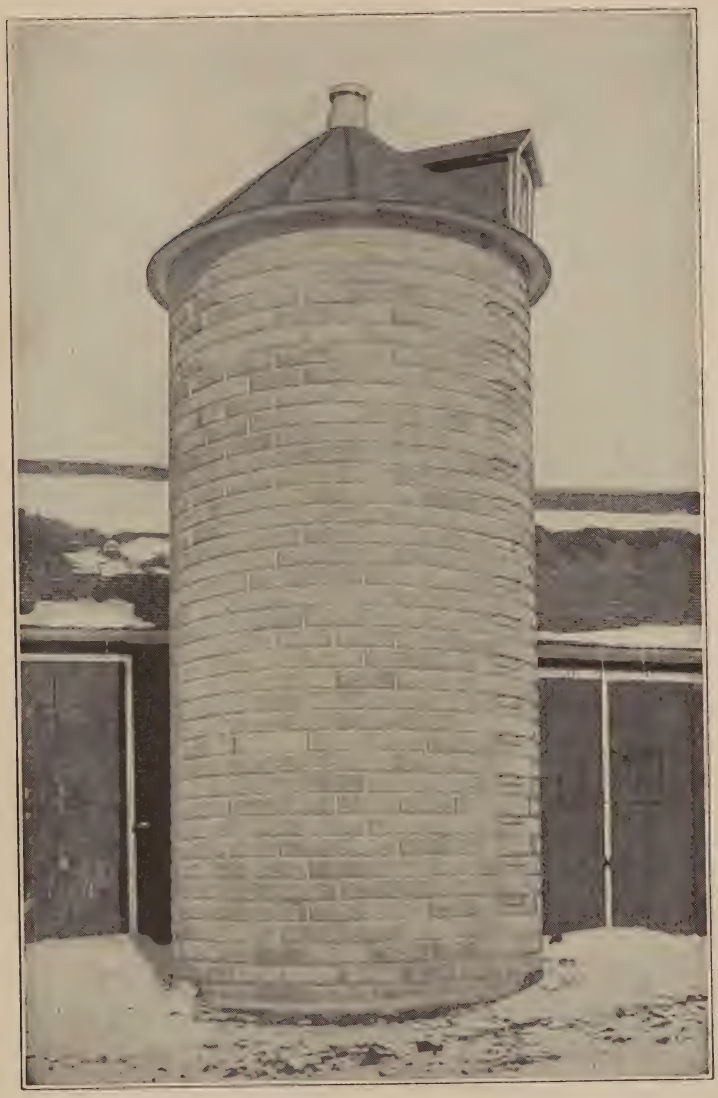


Fig. 35.—Silo built of concrete blocks with double air-space.

as a reinforcing material. The concrete is placed on this, the thickness of concrete dependent on the height of the silo. Both the inside and the outside are plastered with concrete, so the metal itself is not exposed to the silage or the weather.

Cement or Concrete Block Silos.

Concrete blocks are made in two ways—hollow and solid. Practically all silos are built of hollow blocks. The blocks may be made by the farmer himself, or he may buy them from a block manufacturer. If the blocks are bought, care must be taken to secure well-seasoned ones. That is, the blocks must have been made a sufficient time before using to give them time to thoroughly set.

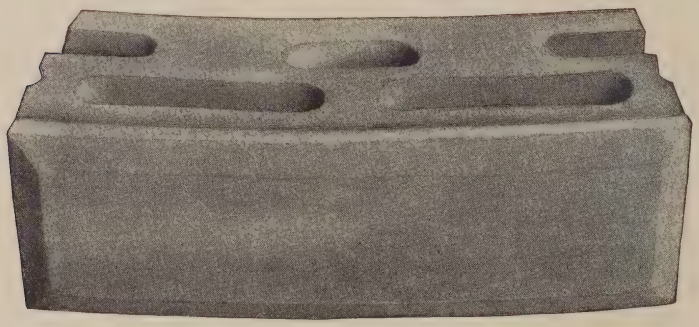


Fig. 36.—Block with double hollow air-space.

For a full description of how to make concrete blocks see our Bulletin No. 1.*

Fig. 34 shows a concrete block silo, the property of W. F. Cowham, of Jackson, Mich. It is 35 feet high and 14 feet inside diameter, built by the Cement Products Co., of Jackson, made on a Monarch block machine. The blocks for the lower third of the height are 8 inches high by 10 inches thick by 16 inches long; the blocks in the upper two-thirds are 8 inches high by 8 inches thick by 16 inches long. Every third course is reinforced with a $\frac{1}{2}$-inch round iron embedded in grooves in the block. The blocks are laid in cement mortar, made in the proportion of 1 part Portland cement to 2 parts sand.

* This bulletin may be obtained by applying to the Secretary of the Association of American Portland Cement Manufacturers, Land Title Building, Philadelphia.

The silo shown in Fig. 35 is built of concrete blocks with a double air-space laid in cement mortar.

The type of block of which this silo is built is shown in Fig. 36

Fig. 37.—Concrete block silo.

These blocks are made on machines of the Miracle Stone Co., of Minnesota. The silo was built by the Schutte Cement Co., of Manitowoc, Wis. It is reinforced with rods running through the grooves in both directions.

Fig. 37 shows another block silo, built by the Concrete Block and Supply Co., of Wausaw, Wis., on the farm of B. F. Wilson. It is 18 feet outside diameter and 30 feet high.

Many successful concrete silos have been built by methods other than those described, but for one who does not know how to handle concrete, the best results will be obtained by following closely the methods described herein.

We have given a great variety of photographs of concrete silos, located in nearly every part of the United States. This, together with the fact that more of these concrete silos are being built every year, conclusively proves that a properly constructed concrete silo is the best kind.

In Bulletin No. 129 of the Maryland Agricultural Experiment Station, on page 73 we find the following paragraph relative to concrete silos:

"When all things are considered the reinforced concrete silo is probably the best and most economical one that can be built. * * * They may be built of hollowed curved blocks made especially for this purpose or solid reinforced walls may be used.

"The later method of construction would probably be the cheaper and more durable and satisfactory."

It would seem that little more can be said in praise of concrete silos.

For further assistance in the construction of a concrete silo, apply to the Agricultural Department, Bureau of Animal Industry, Dairy Division, Washington, D. C.

BILL OF MATERIALS FOR CONCRETE SILOS.

Size of Silo.....ft. x .....ft. inside measurement.

CONCRETE MATERIALS:

..... bbls. of Portland Cement.
..... cu. yds. Sand.
..... " " Gravel (or stone).

REINFORCEMENT:

..... lbs. steel wire No.....gauge.
..... " " " " ..... "

or

..... lbs. round Bars, Size.....inches in diameter.
..... " " " " .....inches " "

LUMBER.

Forms.

.....	lineal ft.	1" x 3"	=	B.M.
.....	" "	1" x 4"	=	"
.....	" "	2" x 4"	=	"
.....	" "	2" x 6"	=	"

Scaffolding and Bracing.

.....	lineal ft.	1" x 6"	=	B.M.
.....	" "	2" x 6"	=	"
.....	" "	2" x 8"	=	"
.....	" "	2" x 10"	=	"
.....	" "	2" x 12"	=	"
.....	" "	3" x 6"	=	"

Roof.

.....	lineal ft.	1" x 6"	=	B.M.
.....	" "	2" x 4"	=	"
.....	" "	2" x 6"	=	"

Chute.

.....	lineal ft.	1" x 6"	=	B.M.
.....	" "	2" x 4"	=	"

Doors.

.....	lineal ft.	2" x 6", or 2" x 8" Tongued and Grooved and Surfaced	=	B.M.
.....	lineal ft.	2" x 4"	=	"
		Total	=	"

SHEET METAL FOR FORMS (AND ROOF).

..... Sq. ft, 24 Gauge Sheet Steel @ .94 lbs. per sq. ft. =.....lbs.

or

..... Sq. ft. 24 Gauge Galvanized Sheet Steel @ .94 lbs. per sq. ft. =...lbs.

SUNDRY ITEMS.

Nails.
Bolts.
1-inch round iron for Ladder.
Waterproofing.
Shingles or other Roofing (if used).
Oil for painting forms.

CONCRETE MIXING PLANT.

See Bulletin No. 20 for Tools and Materials necessary for mixing Concrete.

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LEHIGH
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TRADE MARK
CO
PORTLAND
CAPACITY
12 000 000
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CEMENT
ALLENTOWN, PA.
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